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SCIENCE AND TECHNOLOGY

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CHINA REPORT
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RISK INVESTMENTS IN CHINA DISCUSSED

Tianjin JISHU SHICHANG BAO in Chinese 22 Oct 85 p 1

[Article by Kai Jun [0418 6511]: "Creating a Good Environment for Risk Investments in China"]

[Text] The experience of many countries and regions in the world proves that risk investment is an effective way to promote the development and application of high technology. Pioneer risk investments made opportunely will have a positive effect on our efforts to restructure the existing scientific and technical system and the way we manage capital, on the promotion of science and technology with economic mechanisms, and on the acceleration of the commercialization of high-tech achievements.

At present basic conditions already exist for pioneer risk investments in China. First, our high tech has reached a certain level, both qualitatively and quantitatively. There is a good prospect that technical achievements will be applied and an industrial economy is now in place. Second, a trend toward the reasonable movement of technical personnel has appeared, preliminarily forming an environment in which experts can engage in industrial pursuits. Third, certain coastal areas have developed a relatively advanced socialist commodity economy. A restructuring of the industrial system is currently in full swing, particularly the technical modernization of existing enterprises. The idea of pioneer risk investments is gradually being accepted by all social quarters, paving the way for the raising of capital.

It should be noted in particular that clusters of high tech have already appeared in an embryonic form in certain cities and regions in the country and obtained prominent economic results. These cities and regions all have a strong industrial base and formidable technical resources. They are highly accessible and have a fairly advanced transportation sector. They are geographically well placed to attract foreign capital and obtain foreign technical information. Most important, they have an army of technical and managerial personnel with liberated ideas and a pioneering spirit. All this has laid the foundation for high-tech risk investments and provides a market essential to their flourishing.

Pioneer risk investments are a novelty in China. Even as we learn from foreign experience, we should come up with our own theories and detailed implementation plan suited to China's socialist conditions.

Under the present situation, it is both necessary and feasible for us to establish a number of pioneer risk investment entities. They should not form part of a government agency but should enjoy the independent status of legal persons and function as autonomous enterprises responsible for their own profits and losses. Instead of relying on state funding, they should find their own means of existence and development with support from government policies. They should raise funds from a variety of sources. While some may come from the government appropriation process, most should be investments by sectors and enterprises and money paid for shares. When conditions are ripe, shares can be sold directly to individual citizens in order to channel society's idle money toward the development of high-tech products. During their infancy, risk investment entities may set up risk enterprises on an experimental basis in selected localities, industries and sectors which have the necessary conditions. These pilot projects prepare the ground for future large-scale risk investments.

The primary target of risk investments is small and medium-sized enterprises, both new and existing, which have problems raising funds through the regular channels and are involved in the production of new technical products and technical modernization. The scope of risk investments emphasize the development of information, biomicroelectronics, new materials and other new technical products and include industrial production and after-sale maintenance services. At first risk investment entities may focus on modest projects which yield economic results within a short period of time. As they mature, they may gradually consider taking up larger projects. Given appropriate conditions, we should go in for overseas risk investments and set up branch companies or offices abroad if necessary. We should organize joint ventures with foreign businessmen and enter into joint production with them. This is an important means of solving the problem of lack of funds, attracting advanced technology and talent from abroad and expanding economic results. In addition, we should develop policy research to analyze investment trends and come up with recommendations regarding the strategy of high-tech developments at home and abroad and the approach China should take. We should set up a high-tech information network to provide society with technical services. All relevant units should be brought together to develop managerial personnel to oversee technical investment projects.

Necessary legislation and preferential policies are the guarantee of thriving risk investments, a fact borne out by the experience of many countries and regions. To promote the birth and growth of risk investments in China, therefore, the government should adopt preferential policies regarding, say, taxes and loans, to create a favorable investment climate. Once good policies are in place, risk investments will be able to develop healthily. We believe that through continuous experimentation and exertion to improve itself, the enterprise of risk investments will certainly play a more and more important role in China's socialist modernization.

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TECHNICAL SERVICES MADE AVAILABLE TO RURAL SICHUAN

Tianjin JISHU SHICHANG BAO in Chinese 22 Oct 85 p 1

[Article by Liu Chongjia [0491 6850 0857]: "The Reasonable Mobility of Technical Personnel Benefits the Countryside in Sichuan"]

[Text] Sichuan Province recently organized the dispatch of scientific and technical personnel to the countryside in six ways, which has proved very effective in nurturing the development of small and medium-sized rural and township enterprises, promoting the reasonable mobility of qualified personnel and stimulating their enthusiasm.

The six approaches are as follows. First, organizing a cooperative network of scientific and technical personnel to bring together the technical resources of various military industrial enterprises, large key enterprises, research institutes and institutions of higher education. The result is a technical cooperative contingent which embraces a full array of disciplines. The scientific and technical cooperative network in Chengdu alone has completed 205 technical projects for the outlying counties, which translate into 15 million yuan in economic results. Second, technically superior enterprises can enter into cooperative agreements with localities richly endowed with natural resources to provide assistance geared to the latter's needs. For instance, Qingjiang Meter Company in Chengdu has signed a long-term technical agreement with Xinjin County which is of mutual benefit. Third, establishing various forms of integrated organizations. Within such an organization, technical resources are allocated in a centralized way and technical personnel can make themselves useful on a broader scale. Integrated organizations such as Jialing Motorcycle Co and Changqing Refrigerator Co have all obtained good results. Fourth, setting up scientific and technical service organizations and offering consulting services. They are the problem-solvers of small and medium-sized enterprises and have great vitality. Fifth, military industrial units and institutions of higher education have set up processing bases and integrated testing bases at selected sites. The Nanguang Machine Plant in Chengdu, for example, has opened a glass bottle factory in Guanghan County to take advantage of the area's ample quartz supplies. The machine plant provides technology and equipment. Glass bottles produced by the factory are inexpensive, of good quality and so popular that it cannot keep up with demand. Sixth, lending intellectual support to one's native village. Scientific and technical personnel now working away from their birthplaces are mobilized to contribute to the economic takeoff of their native villages. This approach costs little but is highly effective.

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NATIONAL DEVELOPMENTS

PROBLEMS IN TECHNOLOGY TRANSFER DISCUSSED

Tianjin JISHU SHICHANG BAO in Chinese 22 Oct 85 p 1

[Article by Gao Changwen [7559 2490 2429]: "Some Problems in Technology Transfer"]

[Text] With the popularization of the technical market, technology transfer has obtained outstanding results. This is a radical change from the past when technical achievements were merely "samples, gifts, exhibits" and not "commodities." Some small and medium-sized enterprises, especially those in rural areas and townships, have thus been able to make some headway and a new round of technical achievements has been transformed into new productive forces. However, a number of problems has emerged in the current transfer of technology which merit our attention.

First, the pricing of technical achievements should be evaluated. As a direct reaction to the old tendency to undervalue technology, we now let buyers and sellers in technology transactions negotiate their prices, a practice which has promoted technology transfer. But a trend has appeared toward overpricing, with sellers often demanding exorbitant prices. Some include in their costs all expenses incurred by the research and development of their achievements, including the expenses of personnel not directly involved, thus jacking up their prices to such a level that they end up pricing themselves out of the market. While this may give the superficial impression that technology today commands higher prices, the truth is that the value of technology has not been realized. It is therefore necessary for the seller to have a pricing standard and carry out reasonable economic accounting so that his price reflects the value of his product and the buyer benefits in a visible way. Only then can both buyer and seller gain from the transaction.

Second, when an achievement changes hands, it should be accompanied by on-site technical services. In technology transfer, it is not enough for the seller to provide the buyer with blueprints and data. The transfer of an achievement should be accompanied by the dispatch of technical personnel to offer on-site technical services until the buyer develops the capacity for independent production. It is exactly the lack of technical services which has prevented some rural and township enterprises from integrating the technical achievements they have purchased into their production. Their resultant predicament has tarnished the reputation of the technical market.

Third, the two parties, buyer and seller, should assume risks jointly. In light of their present economic status, it makes sense for small and medium-sized enterprises and those in rural areas and townships to enter into long-term cooperation with units which are technically superior. In technical transactions, sellers try to maximize their gains and minimize their liabilities. This tendency makes for nervous buyers and may even discourage potential buyers. A better approach will be for both parties to undertake joint development, go in for joint production, assume risks together and become long-term partners. In this way, the seller's achievements can be widely disseminated while the buyer's products can be updated.

Fourth, technology transfer must go hand in hand with feasibility analyses and technical planning and demonstrations. To find out whether or not a particular achievement can be rapidly transformed into productive forces in a certain locality, we must do a feasibility study, involve both the buyer and seller in verifying the technical plan and conduct a realistic analysis around such aspects as supply, production and marketing. Specific issues to be examined include resources, raw materials, qualified personnel, technical resources, markets, supply-demand trends, capital and management. A practical technical plan should then be drawn up for implementation on the basis of such an analysis. If we jump on the bandwagon blindly, we will only end up in a passive situation and suffer financial losses.

Fifth, the control of technology transfer must be strengthened. As the technical market flourishes and becomes widespread, there must be appropriate control mechanisms to facilitate its healthy development. Every province, municipality and district must have a centralized functional agency or unit whose task is to bring about control, and, by continuously summing up practical experience, perfect the system over time.

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NATIONAL DEVELOPMENTS

PRIVATE SCIENTIFIC RESEARCH THRIVING IN GANSU

Tianjin JISHU SHICHANG BAO in Chinese 22 Oct 85 p 1

[Article by Ma Tiancai [7456 1131 1752]: "Survey on Private Scientific Research Organizations in Gansu"]

[Text] As the restructuring of the economic and scientific and technical systems become more thoroughgoing, a new scientific and technical force -- private scientific research organizations -- is on the rise. Judging by the results of a survey on such organizations in Gansu, there are three reasons they have been able to flourish. First, the nation's economic structure which allows the coexistence and simultaneous development of various economic forms and operational styles provides the prerequisite for their existence so that they logically become an organic part of it. Second, China's technical market is maturing gradually, generating a demand for new products and information and calling upon a host of dedicated scientific and technical personnel to engage in the production and development of technical products. This makes possible the rise of private scientific research organizations. Third, as the movement of qualified personnel picks up, they can select their jobs through such procedures as transfer, hiring, resignation and no-pay leave of absence, creating a nurturing environment for private scientific research.

According to the survey on 13 private research organizations in Gansu, over half of them have obtained outstanding economic results. Weixing Applied Electronics Research Institute in Lanzhou is a private organization founded by eight technicians whose talents and expertise were unexploited in the past. After setting up the institute, they each came into their own and assumed important tasks. It took just 15 days to build a small television projector for an open transmission system for broadcast and instruction and has already received orders for 15 such machines, which upon delivery will net a profit of 4,500 yuan. The privately-run software scientific research institute helped Anning Auto Parts Factory develop systems engineering management. As a result, the factory's circulating fund turnover period was shortened, the costs of single parts and waste were reduced and output value and profits rose 10-fold and 19-fold respectively over the pre-systems engineering management period.

Though still in their infancy, China's private scientific research organizations have already captured public attention with their special

features and functions. Judging by Gansu's research organizations, we can summarize their managerial characteristics as voluntary association, freedom to pick their own management team, financial independence, self-management, operational autonomy, responsibility for their own profits and losses and independent accounting. Such characteristics mean that these organizations follow a new guiding ideology and personnel policies and have flexible management and strong adaptability. A high proportion of their achievements are put to use with good economic results. They are contributing to economic construction in a way that state-run scientific research institutes cannot. Their professional guiding ideology indicates that they are mainly oriented toward small and medium-sized enterprises and those in rural areas and townships. They usually tackle projects shunned by their state-run counterparts. Take Jincheng Special Instrument Research Institute in Gansu, for instance. It was exactly its realization of the fact that large meter plants and state-run research institutes are not suited to develop isotope meters that prompted it to enter this field of research and development. In the 3 months since the institute came into being, it has formally hired 44 part-time engineers and signed agreements with 22 research organizations, factories and enterprises across the nation to provide radioactive sources, machining, raw materials, components and marketing services. So far it has received orders for 50 machines and expects to assemble 10 to 15 isotope meters by the end of the year.

Private scientific research organizations are a novelty in our scientific and technical reform. Like a young seedling, they need both external support and inner vitality to grow. If the current problems of private scientific research organizations in Gansu are any indication, our tax policy still lacks uniformity and political parties and other organizations have no place to rely on. Moreover, it is uncertain where permission for external technical exchanges can be obtained. The departments concerned must come up with concrete solutions to these and other problems.

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NATIONAL DEVELOPMENTS

RECRUITMENT OF S&T PERSONNEL FROM THIRD FRONT REGIONS BANNED

Tianjin JISHU SHICHANG BAO in Chinese 22 Oct 85 p 1

[Text] The Office of the State Council and the Office of the Central Military Commission recently issued a joint circular reiterating the ban on recruiting scientific and technical personnel from third front hardship areas.

The circular points out, "In the 2 years since the State Council issued the 'Regulations Concerning the Reasonable Movement of Scientific and Technical Personnel,' various regions and departments have done a lot of work, accumulated a fair amount of experience and obtained some achievements in promoting the reasonable movement of scientific and technical personnel and making full use of them. However, there are still some regions and departments which, in violation of government regulations, go to the third front hardship regions at will to recruit qualified personnel, ignoring the "five requirements" (for administrative letters of introduction, wage relations, residence registration, grain and oil and party, league and other organizational affiliation). This wrong practice exacerbates the brain drain from those regions. There have been frequent instances in which technicians left their posts without notice, adversely affecting the stability of the scientific and technical contingent on the third front. If measures are not promptly taken to correct the situation, restructuring efforts and the accomplishment of further tasks in the strategic rear areas will be impeded.

For this reason, the circular reiterates that all regions and departments must not approach scientific research, production and teaching units at the third front to recruit their technical personnel. The movement of scientific and technical personnel at the third front must proceed under effective leadership and in accordance with a plan. When a scientific worker wants to be transferred, he must apply to the organization with cadre management jurisdiction and finalize all handing-over procedures before he can leave. Leave without notice is prohibited. Cases involving people who have left without notice must be carefully handled by the various regions and departments concerned on a case-by-case basis. A person who has graduated from college or secondary technical school since 1982 must be firmly returned to his original unit. When the individual in question graduated before 1982, he should be returned to his original unit whenever possible if his change of job is unjustifiable and his position in the old unit matches his expertise. This requires close cooperation between the hiring agency and the original

unit and an effort to educate the worker ideologically. The original unit should welcome him back warmly and must not discriminate against him. In cases where the change of job is justifiable and where the original unit can dispense with the services of the departed worker, transfer procedures should be carried out retrospectively upon agreement by both sides.

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SIGNIFICANCE OF TECHNOLOGY MARKET DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENTIOLOGY AND MANAGEMENT OF S & T] in Chinese No 9, 12 Sep 85 p 11

[Article by Chang Shijia [2545 1102 1367]: "The Significance of the Technology Market"]

[Text] The development of China's technology market, from its birth to its present boom, has been almost explosive. Within a very short period of time, it has already shown its awesome power.

1. Helps heighten the entire people's appreciation of technical achievements.

In the past, the technical research achievements of scientific research units were perpetually ignored, rejected by production units even when they were delivered to their door step. Now they are hot properties, much sought after by factories and enterprises. Many production units, undeterred by vast distances, scout the technology market for achievements and are willing to pay massive sums of money for them. People have learned from experience that all economic competition today boils down to technical competition. Whoever gets hold of technology can produce good products. The more vital enterprises become, the more fierce their competition, and the more urgent their demands for science and technology will be.

2. Effectively promotes the popularization and application of advanced technical achievements.

In the past, many technical achievements were invented or discovered only to be pigeonholed and remained "gifts, samples, exhibits" for an extended period of time. Today the technology market finds a home for them, thereby effecting the four transfers (from the laboratory to the production line, from military use to civilian use, from coastal areas to the interior, and from large cities to small and medium-sized cities) and soon converting them into tangible productive forces. Production problems which previously proved intractable because of a lack of know-how are now readily solvable through bidding in the technology market.

3. Changes the rigid system of scientific management by administrative decree.

The research plans of scientific research units and colleges and universities used to be handed down by the higher authorities. Even projects which were clearly at odds with practical needs must be completed. Today, scientific research departments engage in a direct "dialogue" with the users of their products and enjoy access to information, which enables them to respond expeditiously and reorient their research in accordance with the principle, "scientific research must produce the kind of results the market wants and serve economic development." In this way, they can devote themselves to tangible, practical scientific projects which contribute to the nation's economic results within the shortest time possible.

4. Helps banish to history the old system in which funding for scientific research was "supplied by the state" and cost-benefit considerations were discounted. Scientific research units have further enhanced their economy-mindedness and sense of social responsibility. They have joined hands with production departments to form an organic entity whose components share a common fate.

5. Gradually puts an end to the depressed incomes of scientific research units and personnel.

In the past, scientific research units and institutions of higher education often "financed the popularization of new achievements out of their own pockets." Nowadays, not only are scientific achievements made over with compensation, but the tendency to underprice technical commodities has also been reversed. In the process, the income of scientific research units and personnel has gone up, which helps boost the creativity and enthusiasm of scientific research personnel to come up with more and better results faster.

6. Bridge the gaps which used to separate department from department, region from region. It has strengthened horizontal coordination and connections and promoted the development of scientific research work in a social direction.

7. Helps abolish the old habit among scientific research units and personnel of "eating out of the same big rice pot." The technology market encourages competition, awards the hardworking, penalizes the indolent and is the driving force behind the further growth, in scope and in depth, of technical development, research, applications and popularization. It also encourages scientific research personnel to continuously upgrade their professional standard and adaptability.

8. Enhances the role science and technology play in decision-making and intensifies the sense of urgency in decision-making departments and among decision-makers about relying on science and technology for economic construction. The development of the technology market will also make decision-making departments and their people strengthen their leadership and interest in scientific research and researchers.

9. Facilitates the further implementation of the policy on intellectuals, improves the social position and working and living conditions of

intellectuals and promotes "the mobility of expertise" and the movement of qualified personnel.

10. The development of the technology market helps bring closer the day when our people will part company with ignorance and benightedness, with decayed ideas of looking down on knowledge and mental workers. It helps cultivate a new atmosphere of respect for knowledge and educated people, attract more committed people to scale the heights of knowledge and promote our scientific and technical enterprise and economic construction.

In short, the development of the technology market has special and profound implications for the comprehensive restructuring of the nation's economic system currently under way.

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NATIONAL DEVELOPMENTS

SCIENCE COMMISSION ON COMMERCIALIZATION OF TECHNOLOGY

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENTIOLOGY AND MANAGEMENT OF S&T] in Chinese No 9, 12 Sep 85 p 2

[Article by Guo Shuyan [6753 2885 6056]: "New Trends in the Technology Market"]

[Text] The basic principle of the restructuring of the scientific and technical system as laid down by the CPC Central Committee is to conscientiously apply socialist commodity economic laws and the market mechanisms in accordance with the objective principles of economic and scientific development in order to achieve a close integration between science and technology, on the one hand, and the economy, on the other. The slogan "Take grains as the key link" was chanted for years, yet our grains problems have not been solved. The same is true for the relations between science and technology and the economy. More than 30 years of experience tells us that if we ignore commodity currency relations and the law of value, we cannot do our job well and may end up with half the results despite twice the effort.

The reasons why we must commercialize technology and go all out to develop the technology market are to change the operational mechanisms of technical relations and speed up the popular application of technical achievements. Therefore the technology market is crucial in the present scientific and technical reform.

At the national trade fair held this March, 8 billion yuan worth of business deals were discussed, the amount of business done amounted to 2.1 billion yuan and purely technical income was 700 million yuan, indicating that the commercialization of technology has entered a new stage. At present the technology market exhibits the following new trends and characteristics:

(1) projects in the national plan are beginning to enter the technology market. For example, the Beijing municipality invited tenders for two batches of projects at the technical trade fair and picked domestic units to undertake some of them. In this way, technical development was promoted, foreign exchange was saved and a duplication of imports was avoided;

(2) there has been a substantial increase in the number of general contracting (turnkey) projects;

(3) research units have been linking up with enterprises for cooperative development and joint operations, their investments being their know-how;

(4) practical technology is becoming more and more popular;

(5) the technology market is nurturing economic growth in old liberated areas, regions inhabited by minorities and border areas with suitable technology;

(6) banks and the financial community are entering the technology market.

Concerning the technology market, some comrades still fear that the commercialization of technology will steer all scientific and technical personnel toward projects which are short-term and yield quick results, with adverse effects on key projects and long and medium-term scientific research tasks. Through command planning, the state, industries and localities will do their best to ensure that this will not happen. We must further improve our system of incentives: all other things being equal, scientific researchers engaged in projects in the national plan should not be paid less than their counterparts working on horizontal contracts.

Certainly the technical trade today still has some problems, eg., the theft of achievements, the dearth of intermediaries, lack of a pricing standard and the breaking of contracts before they expire.

Not long ago, the State Council approved the establishment of the national technology market coordination leading group under the leadership of the State Science and Technology Commission. Its major functions are: 1) establish and perfect a legal system regulating the technology market, eg., technology market management, technical contract law, and a provisional statistical system for technical trade; 2) formulate effective and supportive policies and measures in such areas as prices, tax, credit and distribution; and 3) successfully manage the relations between the state, the collective and the individual in the distribution of profits so as to stimulate the enthusiasm of the buyer, seller and the middleman and protect their legitimate rights and interests. The coordination group intends to put the technology market on the right track in a few years' time.

(This is an excerpt of Comrade Guo Shuyan's speech at the working conference on the restructuring of the scientific and technical system in Tianjin. It is based on notes taken at the meeting and has not been read or approved by him).

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NATIONAL DEVELOPMENTS

SCIENTIFIC RESEARCH THRIVING AT XIAN JIAOTONG UNIVERSITY

Beijing RENMIN RIBAO [Overseas Edition] in Chinese 11 Nov 85 p 1

[Article by Ma Jiqi [7456 7162 3823] and Zhang Guangqiang [1728 0342 1730]: "The Open Door Policy Has Breathed Life into Xian Jiaotong University"]

[Text] In an interview with reporters recently, Professor Shi Weixiang [0670 4850 4382], president of Xian Jiaotong University, said that the open door policy and international academic exchanges have injected vitality into this old university.

From 1979 to the present, Xian Jiaotong University has so far established intercollegiate relations with 28 universities in 7 nations. During the same period over 280 of its faculty and staff members have lectured abroad or been invited to attend international academic conferences.

Xian Jiaotong University grew out of Nanyang School founded in 1896. After the 1911 revolution, it was renamed Nanyang University and acquired the new name of Xiaotong University in 1921. A large part of it was moved to Xian in 1956, hence its present name, Xian Jiaotong University. Its alumni are scattered throughout the U.S., Europe and various Asian nations and Jiaotong alumni associations can be found in the U.S., Canada, Britain, Japan and the Hong Kong region.

The president said that in order to improve teaching quality, the university in recent years has invited over 3,000 foreign professors and scholars to Jiaotong to conduct academic exchanges and appointed 67 well-known scholars as honorary professors or consulting professors. These celebrity scholars have brought to the university the latest technical information in the world and enriched the substance of its teaching.

Meanwhile, Xian Jiaotong University has successively sent 410 teachers and graduate students abroad for further studies. Those among them who are pursuing master's and doctoral degrees account for one quarter of the university's entire teaching staff.

So far 160 have completed their studies and returned to the university and now constitute the backbone of its teaching and research contingent.

President Shi Weixiang said, "As international academic exchange activities and educational reform become more sophisticated, Xian Jiaotong University's teaching and scientific research work have also obtained gratifying results. Since 1979, the university has completed a total of 1,200 scientific research projects and come up with 350 scientific research achievements, of which 43 reach or approach advanced international levels."

The university already has 18 fields of study authorized to award doctoral degrees.

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NATIONAL DEVELOPMENTS

OPENING UP TECHNOLOGY MARKET IN SHAANXI DISCUSSED

Tianjin JISHU SHICHANG BAO in Chinese 29 Oct 85 p 1

[Article by Wang Tingxiang [3076 1694 4161]: "The Technology Market Bridges the Gap between Science and Technology and Economy in Shaanxi"]

[Text] Institutions of higher education and research units in Shaanxi Province are among the nation's leaders both qualitatively and quantitatively. At the first national trade fair, although most colleges, universities and research institutions entered as part of the Ministry of Education or the departments in charge so that their trade volume was not reflected in the figures for Shaanxi, the province still managed to rank third among the nation's 29 provinces, municipalities and autonomous regions. However, Shaanxi's economic performance ranges from poor to mediocre. Our technical achievements are not put to good use within the province but are accepted and applied in coastal cities, with excellent results. A major reason is the communication gaps in the province, particularly in remote mountain areas. There are better communications between Xian and the coastal cities than within the province.

How can we solve the above difficulties? After the technology market began to flourish across the nation, Shaanxi too has found a specific answer to its problems, namely, aggressively develop the technology market, mobilize the entire province's technical forces to take an active part in the province's technology market, strengthen communications within the province, and clear up channels which have been clogged for many years. This approach promises to bridge the unreasonable technical and economic gaps in the province and go a long way toward promoting Shaanxi's economy and the technical advance of its enterprises.

Even as we develop our technology market, we should open our eyes to the fact that Shaanxi has a relatively weak economic base and limited financial resources, making it necessary for us to limit our purchases of technical achievements to what we can afford. We must first realize that the mere purchase of an achievement does not turn it into productive forces. Other costly investments are needed, for instance, to pay for equipment and installations. We must also have available adequate circulating funds to buy raw materials and other production essentials. These miscellaneous investments far exceed the cost of scientific achievements. Moreover, some

achievements may be very advanced and produce outstanding economic results. But we still need a considerable number of technical personnel to work on them, something probably beyond the capability of small enterprises. In shopping for technical achievements, therefore, we must take into consideration various factors such as the resource characteristics of the locality, its financial state, its market and the enterprise's own ability to digest an achievement, and do some hard thinking. The seller too should be honest about what his achievement can do and help his customer turn out good products so that every deal will lead to a success story. In this way, the technology market can act as a real intermediary between buyers and sellers and the economic takeoff in Shaanxi will not be far off.

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NATIONAL DEVELOPMENTS

TECHNOLOGY ASSESSMENT REVIEWED

Shanxi JISHU JINGJI YU GUANLI YANJIU [RESEARCH ON THE ECONOMICS AND MANAGEMENT OF TECHNOLOGY] in Chinese No 4, 31 Aug 85 pp 35-37

[Article by Huang Qingming [7806 2348 2494]]

[Text] I. The Presentation of Issues

The challenge of the new technological revolution we face is not limited to the area of science and technology [S&T]. It is also an economic and social challenge as well as opportunity. Therefore, consolidated measures covering science, technology, economy and society should be studied.

The first issue in developing new technology is the purpose. Why do we want to develop new technology? The answer differs with different social systems. From the economic point of view, the function of technology is to create use value. However, at different historical periods, each class has its own different value orientations. So it cannot be concluded that all new technologies are good technologies and that those technologies successfully applied in other nations are the ones we should also develop. In studying measures for the new technological revolution, the primary question is "what is the fundamental goal of our technology development?".

Technology development is not our goal. Our goal is to revitalize our economy and cause our society to flourish. Stalin interpreted the basic economic rules of socialism this way: to guarantee, on the basis of high level development of technology, that the material and cultural needs of economic growth for the whole society be maximally satisfied by constantly increasing and perfecting socialist production. So it is obvious that technology development is just the means and the ultimate goal is to raise the living standard of the people.

It is agreed that technology developments have far-reaching and profound impact on society and the economy, both positive and negative. Thus, the study of the measures for the new technological revolution should not be limited to the technology itself. Rather, the relationship of technology with economy and society should also be considered. If we simply transplant technologies from the developed countries, then it will create more problems than it solves. Since the end of World War II, the majority of the third-world countries have suffered setbacks in their efforts to advance their economies. One of the deciding

factors is their lack of technology assessment capability so that practical, feasible technological strategies can not be formulated and a coordinated development of S&T, economy and society becomes impossible.

Our party and goverment have set the policy of developing S&T in coordination with the development of the economy and society. To realize this correct policy and to develop the best technologies, one important link is to develop "technology assessment."

II The Emergence of Technology Assessment

The background for the emergence of technology assessment is the extremely rapid development of technology that becomes more widespread and more complicated every day. Its impact on the economy, society and ecological environment is far more than nature and mankind can cope with. The advances in S&T have greatly reduced the lag from the discovery or invention of technology to the introduction of products. At the same time, the advance of technology also makes it possible to assess the danger of technology abuses at the early stage. In order to avoid blindly developing technology, it is necessary to control and manage the development of technology and to establish S&T policy so that technologies can be guided toward the direction of bringing benefits to mankind.

In 1966, the Subcommittee on Scientific Research and Development of the Congressional Science and Technology Committee of the United States pointed out that the new S&T would bring not merely benefits so it was necessary to look out for potential dangers. It demanded the implementation of "technology assessment." Japan and European countries have responded strongly to technology assessment. In 1972, the United States Congress passed the Technology Assessment Bill and the Technology Assessment Committee and its operating arm, the Office of Technology Assessment, were established as mandated by the law.

E. Daddario, the Chairman of the Scientific Research and Development Committee of the United States, has made the following remark on technology assessment: "Technology assessment is a kind of policy study that provides policy makers balanced assessments. An ideal technology assessment must be such an assessment system that it provides, accurately and promptly, good answers to problems."

The Science and Technology Agency of Japan has defined technology assessment as: "to evaluate the guidance of S&T toward the direction of working for the well-being of and making contributions to the people. Specifically, along with the applications of S&T, it is to forecast their impact on the mankind, society and nature and to assess their positive or negative impact and point out a direction for S&T."

Along with the widespread practice of technology assessment, the meaning of technology assessment is ever expanding. From a generalized point of view, technology assessment consists of three parts, i.e., the concept of technology, the assessment of technology and the management of technology. The concept of

technology means the establishment of value orientation toward technology. The original purpose of developing technology is to bring benefits to mankind and to raise the living standard of the people. The assessment of technology is to establish analysis and evaluation protocols for assessing, based on the value orientation of technology, the impact of technology on nature and society and to make them applicable to the assessment of different technologies. The management of technology is to take measures, based on the value orientation of technology and the conclusions of the technology assessment, to insure that technologies are developing toward benefiting mankind and society. In a narrow sense, technology assessment only means the assessment of technology by the various methods of technology assessment.

Generally speaking, the social functions of technology assessment include forecasting, alert and decision-making consultation. If all the consequences of applying a technology are understood and its hazards known during the development of the technology or before its utilization, the development of the technology can be correctly guided and its correct usages recommended. To assess the pros and cons of S&T and, when there is the possibility of malignant effect, to take remedial measures or to minimize the effect are the subjects technology assessment deals with. Furthermore, technology assessment has to closely align technology selection with the S&T policy of the individual country. It is to ascertain what direction of technology development the country shall take, what technologies shall be imported in the move toward that direction, how to manage the imported technologies, and what kind of research and development shall be carried out. Technology assessment can have various influences on the S&T policy of a nation and it provides the basis for the formulation of S&T policy.

The task of technology assessment is to make the objective analysis of the new, difficult and often highly-technical problems. It studies the complicated issues involving S&T and presents all possible alternatives, including policy choices, and their potential effects. In order to have accurate, comprehensive, objective, unbiased and authoritative technology assessment, each assessment project shall be participated in by distinguished scientists, engineers, local and citizen representatives.

The basic feature of technology assessment is to assess technology issues from the angle of public welfare. Therefore, it not only analyzes the costs and gains from the aspect of economic benefits but also assesses the overall impact of technology on the economy, society, politics and ecology. Hence, the assessors must include various kinds of specialists. The importance of technology assessment has been increasingly obvious that it becomes imperative. In addition to the attentions paid by governments of the world to the large-scale assessment of technology, many enterprises have also been actively utilizing technology assessment.

III Methods and Procedures of Technology Assessment

There is no unique method in technology assessment. Rather, it utilizes the knowledge and methodologies accumulated and developed in various disciplines including the natureal and social sciences.

The study of the methodology for technology assessment is aimed at formulating criteria of assessment so that the impacts of various new technologies can be systematically assessed. This is based on the believe that it is totally possible to evaluate the impacts of various technologies on the economy, society and other areas by scientific methods so that specific goals can be reasonably decided upon and better technologies can be selected to realize these goals.

The technology assessment in the United States not only evaluates the impact of applying a certain technology, but also includes the assessment of the alternatives, forecasting the areas that would be affected and evaluating from various angles. It includes the following methods:

1. Methods for screening inappropriate technologies.

2. Methods for containing and controlling the environmental impact of technology.

3. Methods that are compatible with the national goals and the social development.

4. Methods by which the government manages research and development.

5. Others: such as technology forecast, environmental analysis, technology transfer analysis, and safety assessment.

Technology assessment methods can be divided into two categories: 1) The problem-based type, in which the best alternative is sought for a known problem; 2) The problem discovery type, which starts with the discovery of problems and continues until the best, appropriate solutions are found for the problems.

Since the 1970s, foreign countries have included technology assessment as part of policy study and it has been widely used in formulating policies and plans. Japan has also paid attention to technology assessment and sent a large delegation to the United States to learn more about it. With the support of the Science and Technology Agency and the Ministry of International Trade and Industry of Japan, new assessment methods and procedures have been developed and applied to a large number of cases.

Having learned lessons from their experience in economic development and technology imports since the end of World War II, developing countries are paying attention to technology assessment and give it new substance and methods to fit the situation of a particular place at a particular time. For example, the main purpose of technology assessment in India is to clarify how much can new technologies help bring about the realization of the main national goal of generally raising the living standard of all the people. They believe the fundamental and ultimate yardstick of technology assessment is "the standard of living and not the number of products" and have formulated the technology assessment methods that are suitable for the situations and customs of India.

As to the specific methods of technology assessment, they differ depending on the subject, level and stage. There is almost no single method that is applicable throughout the whole process. Most are only suitable for a certain area of technology assessment. The "Delph's Method" is applicable to the qualitative forecast of uncertain factors; the "Branch-and-bound Tree Method" is used for the analysis of the inherent relationship between different effects and factors; the "Cross-Interference Matrix" is applicable to the assessment of positive and negative effects; and the "Brain Storming" is suitable for generating alternatives in technological innovation.

Because of the short history of technology assessment, its methods and procedures are not standardized and is dependent on the analytical ability of the assessor. The procedures and methods of technology assessment need further development, especially methods for quantitative assessment.

IV Understanding Technology Assessment

Technology assessment is a new undertaking and is not mature both in theory and in methodology. And there are different understandings of technology assessment.

Although initially the result of the negative effects of technology that caught the attention of the public and government, technology assessment is meant to make correct choices and development of technology. In order for us to realize the magnificent goals of our economic strategy within a short period of time, our guideline for technology selection is "appropriate, advanced technology," which means that the advanced technologies chosen must be appropriate for the situations of our country and be economically reasonable. Besides, at the moment our appropriate technologies must consist mainly of the advanced technologies. There is no doubt that this is a correct guideline. However, to be specific as to what qualifies as appropriate and advanced requires not only qualitative analysis but also quantitative specifications. Thus, it is necessary to carry out technology assessment by integrating the knowledge of economics, sociology, physics, chemistry and geography so that a complete and sound system of defining modernization goals and of modern assessment guidelines can be established to provide a basis for decision-making on the selection of alternatives.

Technology assessment is developing rapidly at the moment and is becoming increasingly popularized, diversified and internationalized. Technology assessments are carried out by the specialized organizations to forecast the future of new technologies, to analyze advantages and disadvantages, to point out the possible consequences of each policy choice and each alternative, to point out what is feasible and what is not through multifaceted and multiangled analysis and to point out the short-term and long-term as well as primary and secondary effects of each choice so that they can help make the right choice. Of course, technology assessment cannot necessarily guarantee correct decision-making, but with technology assessment, the possibility of error is certain to be greatly diminished.

The importance of technology assessment is especially obvious under the circumstances of the new technological revolution. To introduce the theory and methods of technology assessment into our social, economic and S&T decision-making mechanisms and to apply and develop them according to the real situations of our country will help choose technologies correctly and accelerate the pace of our socialist constructions.

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EDITORIAL EXPLORES TECHNOLOGY IMPORTATION PROBLEMS

Tianjin TIANJIN RIBAO in Chinese 18 Oct 85 p 1

[Editorial: "Strive for Self-Development"]

[Excerpt] To attain the correct objective in importation, we must first bear in mind the overall situation. We have to pay for imports in foreign currency. In deciding on the items to be imported, therefore, we must bear in mind the overall situation, think of the need to earn foreign exchange for the state, and give priority to those items that are capable of earning foreign exchange more quickly and in larger amounts. We must not stress imports without giving any thought to earning foreign exchange through exports. In spending foreign currency, we must exercise careful calculation and strict budgeting. Our precious foreign exchange must not be used on indiscriminate foreign purchases, and we must not waste a single moment in mastering and applying the imported technologies in order that they may be put into operation quickly and earn foreign exchange for the state. Thus, with money in hand, the state can increase its imports in an effort to catch up with the advanced world standards.

Second, in importing technology, we must think of the possibility of domestic production instead of stressing general assembling and neglecting the basic work. Now, some people are interested only in general assembling lines and have imported some production lines that are not urgently needed and usually leaving a "long tail." If foreign parts were not available, they would become heaps of scrap metals. The Tanggu Valve Plant imported some advanced technology and quickly used domestic raw materials to produce samples which were up to the international standards. All the accessories were procured at home and the plant won the initiative of self-development. Now let us suppose that we have a "rice-cooker" and some other people have the "rice." If we have no source of "rice" for the "rice-cooker" we brought, we still cannot prepare a meal.

Third, we must seek truth from facts and attempt only what we are capable of . We must not confine our attention to what is "large, foreign and complete" and forget what is "small, high-standard and

specialized." Being "foreign" does not exactly mean being advanced, and even being advanced is only relative. Now some comrades have a new obsession: Whenever importation is mentioned, they want to have large projects with heavy investment, and hope for sets of completely "foreign-made" equipment. These projects are slow in going into operation and producing results, and require long construction periods. After spending all the time and money, it is still hard to predict how the result will be when they eventually go into operation. In this age of "knowledge explosion," new technical developments are taking place every day, and the longer the construction period, the more likely will it be for advanced technology to become backward. By importing projects that are small, high-standard and highly specialized, we can quickly produce special commodities that are of a high standard and able to find a foothold on the international market. When we are so tight in foreign exchange, it is very important that we should give priority to the "small, high-standard and specialized" projects.

We must proceed from the overall situation and strive to earn foreign exchange for the country. We must also master and apply the imported technology as soon as possible to promote domestic production. In importing technology, we must seek truth from facts, have a keen sense of professional responsibility, and be willing to make hard efforts. At present, we must learn from our previous experiences and avoid the detours as best as we can in order that our work of importation may develop in a healthy way and with the correct orientation.

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LIAONING IMPORTS OF TECHNOLOGY, EQUIPMENT DURING 6TH FYP

SK160735 Shenyang Liaoning Provincial Service in Mandarin 1030 GMT 15 Dec 85

[Text] During the Sixth 5-Year Plan period, our province has taken active but prudent steps in importing advanced foreign technology and equipment to promote the development of technological transformation and production in industrial enterprises. In the past 5 years, contracts involving a sum of $900 million were signed, showing an average annual increase of 89.2 percent. In the past 4 years the light industrial units imported the greatest number of technological items and equipment, and the next to follow were the machinery and textile industries. Last year the imported technology and equipment helped more than 500 enterprises carry out technical transformation and helped bring 1.41 billion yuan of output value, and 570 million yuan of profits and taxes, and create $290 million of foreign exchange through export in a year.

During the Sixth 5-Year Plan period, our province has increased the varieties of machinery products and improved their quality, and has provided many major and important technical equipment of international level of the present age for the state key projects. During this period, our province has 6,827 products listed in the state plans, showing an average annual increase of 446 products. The number of products of international level of the 1970's or 1980's rose from 10 percent in 1980 to 32 percent. Some 61 machinery products won state quality awards, an increase of 10 times over 1980, and 179 products won ministry-level quality awards, and 360 products won provincial quality awards, showing an increase of 4 to 6 times respectively over 1980.

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NATIONAL DEVELOPMENTS

CONSEQUENCES OF SCIENTIFIC, TECHNICAL RESTRUCTURING

Beijing ZHONGGUO KEJI LUNTAN [FORUM OF SCIENCE AND TECHNOLOGY IN CHINA] in Chinese No 1, Sep 85 pp 23-25

[Article by Luo Wei [5012 0251]: "A Brief Discussion of Strategies for the Development of Science and Technology"]

[Text] Many areas, departments, and professions are looking closely at developing trends in the world-wide new technology revolution with an eye on the overall strategic goals proposed for the end of this century by the Central Committee, and are studying each development strategy. Developmental strategies for science and technology naturally become an important component among these development strategies.

On the subject of developmental strategies for science and technology, many comrades have already issued a number of worthwhile ideas, and many areas and departments have already begun formulating plans, so here I will just express my views on a few problems.

I. On Scientific and Technical Capabilities

When speaking of the development of science and technology, we can neither progress gradually from our current level, nor depart from our current base. Capabilities in science and technology are the most important base.

First, generally speaking, scientific and technical capabilities include the capabilities for research and innovation, the capabilities for technical exploitation, and the capability to apply technology to production. These three things are intimately connected, but cannot be confused.

The capabilities for research and innovation refer to discovery and invention. This includes what we commonly speak of as basic research and also includes the applications research that is capable of bringing great advances in science and technology. This kind of capability is extremely important, but it is primarily "in the background," being not too easily used to immediately raise the level of production, and not necessarily being even quickly used to raise the level of technology. Even if a laboratory comes up with very good results, they cannot all be applied.

But the importance of this kind of capability is not completely "in the background," but rather can still provide theoretical guidance and supplemental knowledge for advances and improvements in existing technology; in its ability to understand trends in the development of science and technology and in its evaluative ability in selecting technology; and also in its ability to train and raise the levels of personnel. There is another point, a point that possibly we often ignore and that is even felt by some to be not worth considering, namely, that this capability can train a spirit of seeking, of investigation, of innovation, and of discovery. In scientific and technical fields, where there are new discoveries in science, or where there are the examples of people who have made great discoveries in technology, there is a tremendous educational and inspirational capability for youth. We may say that the spirit whereby a people seeks knowledge, where they innovate and invent, is not inferior in its important significance to a competitive spirit; or in other words, this is a manifestation of the competitive spirit in intellectual and technical fields.

Of course, this sort of research need not blossom everywhere. Abroad, it is primarily concentrated in national laboratories, high level universities, and the research and development departments of larger enterprises. Among Japanese enterprises, developmental work stands at 75.7 percent, while basic research and applications research are at 24.3 percent (basic research is 4.7 percent of that), while in universities developmental work is at 5.7 percent; the proportion of developmental work in research organizations is not as much as one half. This shows the necessity for appropriate division of labor and emphasis.

The capability to exploit technology. This includes transforming knowledge and theory into usable technology, advancing and improving existing technology, providing responses to technical questions posed by production, and absorbing advanced technology imported from abroad. Regarding the improvement of economic strength, a technology exploiting capability is extremely important, especially when viewed from the characteristics of the development of current technology, for current technology still has great room for development and a broad field of application. The theories behind things like microelectronics and computer technology are already clear, but the degree of integration is still being improved, capabilities are still improving and the scope of applications is still being expanded. From the point of view of the situation in China, because standards of technology and production are still rather backward, to import and absorb advanced technology from abroad and to renovate and renew technology in all fields poses a great number of technical problems that need urgent solution. For local areas, departments, and enterprises, the most important ones are to foster and enhance capabilities in this area.

The capability to apply technology to production is currently one of our very weakest links and it is a very complicated problem. Because it involves not only science and technology departments and production departments, but also involves basic structures throughout society. I would like to explore this further.

Second, indications for evaluating scientific and technical capabilities are generally chiefly by looking at the numbers of scientists and technicians and the amount of outlay for research development. Obviously, it is not enough to look just at these two figures, and the number of registered patents, the amount of technical trade, improvements in labor productivity, the proportion of highly technical products, the numbers of papers published, etc., should also be included. These indications ought to be integrated in evaluation. At the same time, the situation for distribution of the numbers of scientists and technicians should be examined, as well as whether or not they can be better utilized. This is certainly related to the levels and efforts of the scientists and technicians, and even more importantly to social conditions.

Third, some scholars abroad also regard funding capability as a component part of scientific and technical capability, which is reasonable. What they mean by funding capability is not only in whether or not there are funds, but also in the evaluative capability for funding directions, that is, evaluation of projects, feasibility analyses, etc. This also includes the capabilities for design, engineering, and the provision of equipment. In China, this concept is perhaps less important. In recent years there have developed various scientific and technical consulting companies and consulting services that have paid increasing attention to technical and economic evaluation, and these evaluative capabilities for improving investment serve a very important function; but this sort of work is invariably limited to a narrow scope and to smaller projects. Funding capabilities directly effect whether or not technology can be applied to production, and is a key and central link between technology and production.

II. The Selection of Technology

After strategic goals have been determined, there is a series of processes for the selection of particular goals. Due to the effects of trends in the new world technology revolution, a number of local areas and departments often focus their attention on areas like microelectronics, computer technology, biological technology, and new materials. These technologies are undoubtedly extremely important, but whether each area and department needs to concentrate on developing these is worth study. If during periods of great leaps forward each area developed atomic energy, semiconductors, computers, and electronics, facts have shown that this would not be successful. The reason would be that we are not ready in two different directions: one is that our scientific and technical capabilities are insufficient, and another is that it is not socially necessary. We need now to look at the problems of both directions equally.

Selection in these technical areas is an important point of development, and requires consideration as to how it is to be done, as well as in which aspects it is to be applied. As I say later, these areas are certainly nurturing new breakthroughs, as with the fifth generation computer and gene engineering, but they require great expenditures of time and money and will not see application in the near term. Therefore, we ought to carry out research through the institutes of the scientific academies, higher level universities, and the central research academies and institutes in all departments, but not just everywhere. The primary capabilities of local areas and production

departments ought to be in quickly absorbing existing results (both domestic and foreign), applying them, expanding the fields of application, as well as forming the capability for batch production. Here we should make special efforts in those things that are in large quantities and of broad aspect. That Japan is currently in technically advanced fields is chiefly because of large scale production of cameras, watches, household appliances, music equipment, and television equipment; those fields where production quantities are not great but where technical requirements are still high do not have many advantages in Japan, or the level is lower than that of the United States or Western Europe. This experience is very worthwhile noting. There are biological technology companies in the United States run with great vitality that use various technologies to foster new products for tomatoes and corn. That technology is new, but certainly does not use gene engineering methods. Once some foreign Chinese businessmen and scientists suggested that we use biological technology to improve the fermentation of soy sauce, the intention behind this suggestion being the hope that we would be interested in the large quantity, large scale aspects. In the past we have had many technical achievements that have not constituted production capabilities for reasons of the selection of technologies, and also because society as a whole had not put much attention to changing them into large scale production.

Everyone agrees that Japan has been successful with imported technology, but in addition to other factors, there is one problem that is worth attention. Japan imported quartz technology from the American Bell Laboratories. At that time, and aside from defense uses, the United States was using that technology chiefly for hearing aid devices, while Japan then used it to develop semiconductor receivers, taking several years to do that. Although the first quartz receivers were not first made by the Japanese, it is the Japanese who command the market in large scale production. The Japanese have used the American invented liquid crystal for pocket calculators, commanding that market also. This shows that the problem of what to do with imported technology is a very important one, and that it is of benefit not only to improving our technical levels and improving existing production capabilities, but also for considering the future of development. Regarding this, one thing is that we need vision as well as evaluative capabilities; second, that we must make a large effort. If we are aware of this problem, then the current debate about importing foreign technology and developing domestic research can perhaps be better resolved.

III. A Creative Environment

However we are to fully exploit our scientific and technical capabilities will require us to have an appropriate environment. When considering developmental strategies we must be concerned about this kind of suitable environment.

The U.S. Silicon Valley has attracted the attention of all countries, and many countries are in the process of developing their own silicon valleys, silicon islands, and silicon plains. According to some scholars, Stanford University played a key role early in the formation of Silicon Valley by providing scientific and technical personnel for the high technology companies in the Silicon Valley, and being able to provide exploitative scientific technology and knowledge, as well as the land for buildings. Climatic and living

conditions are quite good there, which in the beginning was also an important factor. Because emerging high technology companies are rather fragile, they rely to a great degree on the help of suppliers of raw materials, financial subsidizers, the marketplace, and other basic facilities. While risk capital is one of the key factors in the basic facilities, one third of American risk capital companies are concentrated in the Silicon Valley. In the mid 1960's, after the Silicon Valley had started on the road to development, exchange of knowledge and information played an increasingly important role.

This shows that we need more suitable geographic environments, scientific and technical environments, legal environments, and market and information exchange environments.

Although geographic environments are certainly not decisive, they should be taken into consideration. Some regional climatic conditions would not be too advantageous but of course cannot be changed, but conditions for transportation, living, and cultural and educational facilities are all alterable. Some lessons from experiences learned from the past construction of Sanxian are known to everyone, but to develop high technology we must take these problems into consideration.

The scientific and technical environment is primarily talented people, but also includes the provision of instruments, equipment, and reagents and materials, supplemented by machining and maintenance conditions and technical workers. In keeping with the restructuring of the economic system, China needs to consider overall requirements for developing science and technology, needing sufficient attention and suitable arrangements for instruments, meters, reagents, and materials.

In the aspects of laws, decrees, and regulations regarding the development of science and technology, China is not yet fully prepared, while some of those do not suit the needs of scientific and technical development. Based on a survey of two professions in Shanghai, profit on old products averaged 22.4 percent, whereas that on new products was 13.7 percent. This shows that it is not easy for new products and technologies to show their advantages in terms of economic results immediately in the early stages. In another sense, it also shows that we lack necessary beneficial measures for supporting new products and new technologies. For several important developed countries, expenses incurred by enterprises during research and development are not taxed or taxes are reduced, and for some, the portion assumed for developing new technology for the government is completely provided. In addition to this, scientific and technical development also needs to obtain legal safeguards and support for things such as patents, contracts, credit, and tariffs. Aside from this, as in the American Silicon Valley, in Palo Alto alone there are 850 lawyers who in addition to being conversant with various laws and regulations, play key liaison roles for rising new companies, even helping entrepreneurs write up venture plans and bringing together entrepreneurs who have inventions and creations with capitalists who have money.

As for the environment for information exchange, and in addition to reading books and printing and publishing, person to person direct exchange has played

an increasing role in this situation where technology changes in a flash. This requires an expectation, atmosphere, and environment for exchange.

The conditions described above certainly cannot function directly in the development of our economy, but their importance is not less than that of scientific and technical accomplishments themselves. We could even say that if we are to achieve even more and better results, as well as whether these results can more quickly and better be applied, will to a great degree be resolved in whether or not there is this sort of suitable environment. Therefore, this must necessarily become an important matter for scientific and technical development strategies.

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GENERAL DISCUSSION OF NEW SCIENCE, TECHNOLOGY POLICIES

Beijing ZHONGGUO KEJI LUNTAN [FORUM OF SCIENCE AND TECHNOLOGY IN CHINA] in Chinese No 1, Sep 85 pp 11-14

[Article by Yu Guangyuan [0060 0342 6678]: "Correct Science and Technology Policies Are Supporting Developments in the Chinese Economy and Society"]

[Text] I have been working with Chinese science and technology management for 30 years. Taking up the topic that correct science and technology policies are supporting developments in the Chinese economy and society, I would like to speak today of some of my personal observations and feelings.

I would like to say first that China's scientific and technical capabilities are not insignificant. Whether from the point of view of quantity or quality we can still say this, and statistical figures cannot completely explain this problem. But when a country has nearly 7 million natural scientists and technicians (1983 statistics showed 6.852 million), that is never a small number. There were 9,344 specialty scientific research organizations in 1983, with total personnel of 1.2 million, which is not a small figure either. There are many very outstanding talented people in Chinese scientific circles, and outstanding talent has begun to appear in recent years among younger scientists in great numbers. When we older workers in science and technology see this kind of situation, we are very gratified.

I would also like to say that China's scientific and technical organizations are not backward. Thirty years ago China formulated a national full-scale long-term science and technology development plan. That was our "1956 to 1967 12 year plan for the development of science." At that time there was hardly anything comparable in the world. And as this plan was being set up after approval, it had the task of implementing a specialty committee for the central government for these kinds of plans, which would also appear to be one of the earliest such things. Also, this kind of organization kept establishing government organizations down to the county level, which have remained to this day. That kind of national, full-scale, and long-term science and technology development plan was first formulated in 1956, formulated again in 1963, a third time in 1978, and what we are currently studying is the fourth one.

Problems that still exist in Chinese science and technology are that although our scientific and technical capabilities are not considered small, nor our science and technology organizations bad, our science and technology still can never satisfy the requirements for building a modernized socialist economy, and we can also say that our science and technology is quite insufficient to help build our modern socialist economy, and it supports that building quite inadequately.

Of course, that we speak this way is certainly not to look down upon the great contributions Chinese scientific and technical circles have made in building our economy. The majority of our important scientific and technical accomplishments would be hard to express in a few words, and it would be this way whether using statistical figures or writing out a list. Scientific and technical circles have put great efforts into the building of our economy. One point in particular especially caught the attention of Comrade Deng Xiaoping at a national science and technology working conference held on 7 March of this year. He said to the scientific and technical circles: "You have not only produced many scientific and technical achievements, but, with an attitude of being your own masters, have made many good suggestions for our nation. Our scientists, professors, and engineers have gone to factories, have gone to local areas, have been welcomed everywhere and everywhere have been asked to discuss strategy, to discuss the long-range view, to discuss plans, and for scientific and technical specialists to participate this broadly in economic and social decision making activities has never happened before in our many thousand year history." This was said to scientific and technical circles, and if he had been speaking before economists I think he would have said the same thing. Because economists work with scientific and technical specialists, because they discuss strategy everywhere, discuss long range views, and discuss planning, and because they broadly participate in economic and social decision-making activities. However, even though we can say so much about the contributions of scientific and technical circles to economic development, we still have reasons to be dissatisfied with the current situation regarding scientific and technical circles, and feel that China's scientific and technical circles have not played a full role in production management. The role that the scientific and technical work of our nation has played in building our socialist economy is not at all commensurate with the capabilities it has today, nor with the organizations that have already been established.

So where then lies the crux of the matter?

For many years now people have been discussing deficiencies in the science and technology system. This point that there are problems with the science and technology system is like the fact that there are problems in the economic system in that they have been noticed for quite some time. During the "cultural revolution" there could not of course have been anyone to be concerned about problems with the science and technology system. But after 1977, at every national conference to discuss science and technology policies and principles and planning for science and technology, it could be said that there was never an occasion that did not touch upon problems in the science and technology system, and each time discussions on this problem were numerous. Especially in these years since the 3d Plenum of the 11th Party

Central Committee, and since our reform of the economic system has had such obvious success, there has been much inspiration in science and technology circles, and the science and technology system has increasingly been felt to be an object of necessary reform. In discussing the question of restructuring the economic system at the 3d Plenum of the 12th Party Central Committee, many comrades have advocated discussing at the same time the question of science and technology system reforms and educational system reforms, but consideration of reforms in the science and technology and educational systems are extremely important topics in themselves, and if we were to restructure science and technology and education we had to study the many problems in the restructuring of those two aspects more deeply and in greater detail. Consequently, among the resolutions of the 3d Plenum of the 12th Party Central Committee was a resolution calling for the exclusive convocation of a special conference and for formulation of special documents.

The "Resolution Regarding Restructuring of the Science and Technology System" passed by the Central Committee in March 1985 was an extremely important document in the history of Chinese science and technology. We can predict that its effects will not be limited to science and technology itself, but will directly effect the building of China's socialist economy. I believe that what is most important and of key significance in it is in the aspect of operational mechanisms, chief substance of which is a restructuring of the funds allocation system and the opening of technical markets.

Let us think about this situation: of those more than 9,300 research organizations that I spoke of before, 5,700 are chiefly responsible to the highest levels and are supported financially by the highest levels. Because China's scientific research outlay is small, there is at the moment no momentum to change, and among the 500,000 scientists and technicians in these organizations how could we avoid wasting their own most valuable time because there would be nothing for these organizations to do? At the same time, the million medium and small, village and township enterprises in this country, the entire countryside of this country, and the relatively backward areas of this country urgently need scientific knowledge and need technology. Innumerable examples in all areas of China have shown that as soon as any enterprise receives the help of scientific and technical capabilities it will quickly reap great economic results. With the help of Tianjin's scientific and technical personnel, the formerly poor Daqiuzhuang in the suburbs of Tianjin Municipality has doubled its annual output value each year since 1977, until by 1984 this area of only some 3,000 persons created a gross industrial and agricultural output value of 60 million yuan, with a net income of over 10 million yuan. The output value reached today by this small village is in no way inferior to that of entire counties among China's poorer counties, even exceeding them. Even if on the one hand a large portion of scientists and technicians in research organizations heavily supported by the nation are undertasked or even totally without work, in another sense the great mass of medium and small enterprises, the great countryside, and the extensive backward areas will suffer in being deprived of scientific and technical capabilities. Therefore, it was provided in the resolution regarding system restructuring to gradually reduce annually the tasking outlay for technically exploitative research organizations, and to use the tasking outlay that is saved together with annually increased scientific research outlays to sign

contracts with research organizations with the state based upon tasking; with the excess scientific and technical capabilities after contracting with the state, they will be encouraged to go to enterprises, local governments, and into society to find topics for research. At the same time, it has been determined to call for the opening of technical markets. This is an important condition for operational mechanisms in the work of restructuring science and technology, and is an important condition for better developing scientific and technical capabilities in economic work. During the 3 months before this resolution was produced, many experiments were tried in this regard, with successful results. This will allow us to more confidently produce this sort of important resolution.

Working in this way is according to reasoning that has never been difficult to understand, but coming up with this sort of resolution was neither taken lightly nor easy to do. There has been in China the idea that sees a socialist economy and a commodity economy as incompatible as fire and water. According to this kind of thinking, even among those material goods that are of practical value and valuable, a significant portion have been viewed by people as things that should not be commercially produced, nor should be sold commercially, and much less should scientific and technical accomplishments be vital products. Although this sort of view has constantly been challenged, even incorrect thinking is not easily removed from the stage of history, but requires an creative attitude toward Marxist theory to replace the dogmatic attitude toward Marxist theory. This requires discussion in scholastic circles, scientific and technical circles, and economic circles, and requires proof through trial. That the resolution on restructuring of the scientific and technical system was produced after the resolution on restructuring of the economic system is logical. The logic is that the resolution regarding restructuring of the economic system has solved the question of whether a socialist economy is also a commodity economy. On the question of scientific and technical patents, to produce this reformist resolution concerning the opening of technical markets is also a situation where success comes when conditions are right and things are settled at the proper time.

Regarding this question of whether a socialist economy is also a commodity economy, I also have a personal view. I believe that to develop a socialist economy, not only ought we to acknowledge that material goods are commodities and permit them to enter the marketplace, but also that nonmaterial goods may also enter the marketplace as commodities according to the needs of developing a socialist economy. The former situation I have called "commodity acknowledgement." That latter situation I call "commercialization" (the sense of "commercialization" I use here is not necessarily the same as the sense when others use this term. I use this term under my own definition). I am certainly not advocating the "commercialization" of all nonmaterial goods, but rather that all things beneficial to developing a socialist economy, whether or not they have value, should be considered "commercializeable." Scientific and technical accomplishments are just the kind of nonmaterial goods that ought to be "commercialized." Only by explaining clearly theoretically that we can permit this "commercialization" and opening up technical markets, can we get rid of ideological obstacles and proceed in a smooth way.

There is a theoretical question in the Marxist economic system that is worth discussing here. This category of "value" occupies a very important position in Marxist economic systems. Marx proved in "Capital" that the value of a commodity is not the respective amount of labor expended in its production, but rather is determined by the average amount of socially necessary labor needed to be expended during its production. In "The Theory of Surplus Value," Marx expanded the concept of "value" outside labor, because to generate an act of labor one must expend effort, even to the extent of expending material labor. Therefore, labor has both practical value and value. However, I believe that although a great deal of labor is expended in obtaining scientific discoveries and technical inventions, as well as a great deal of intellectual effort, within the same period of labor, the intellectual effort that is made is often the equivalent of several times the amount of labor in simple labor. But according to Marx's definition of value, this sort of labor does not constitute value. Because value is constituted over long term, in great amounts, and through repetitious exchange, scientific and technical accomplishments are the same as artistic creations, where each commodity is "unique." A second similar commodity, even if not plagiarized, still loses its qualification and significance as a created object. This sort of commodity production also does not constitute an average amount of socially necessary labor. But that scientific and technical accomplishments do not constitute value in Marxian economic theory, this certainly does not keep them from having a price during exchange on the marketplace. There are many things in a commodity economy that have no value but may also have value. It was in this spirit that I read the rule written in "A Resolution Regarding Restructuring of the Science and Technology System" that goes "The market price for technical accomplishments is determined by the two exchanging parties, and which the state will not restrict." I do not believe that the price of technical accomplishments is based on their value, because as I said before this basis does not exist. Of course this is only my opinion, and I do not demand that other comrades hold the same theoretical viewpoint.

When opening up technical markets and changing the system for allocation of funds, the resolution drafters understood that because there are scientific and technical activities of different kinds, they could not use the same method to deal with scientific activities of different sorts. The scientific and technical system restructuring resolution has only "for technical development and applications research the practical value for which may be expected in the near term, a technical contractual system should be gradually promoted." The "Resolution" provides that "for basic research and partially applicable research, a scientific fund system should be tried out, the sources for that fund chiefly coming from allocation of funds from the national budget," and "for those research organizations engaged in activities of general benefit to society, such as medical hygiene, labor protection, planned births, disaster protection, and environmental science, as well as those organizations that are working in scientific and technical service and technical basics like information, standards, measurements, and observation, outlay will still be by the state under an outlay responsibility system." For scientific and technical accomplishments to enter the marketplace as commodities there must be a customer. After buying a scientific or technical achievement, a customer will always want it to be able to bring him economic results before he will be willing to put out the appropriate price. Some

scientific and technical achievements are of benefit to society, and therefore the state ought to compensate for the research outlay. Our nation wants to represent social benefit and long-term benefit, so categorical management of outlays is essential.

We can also imagine the kind of scientific or technical achievement that would bring economic results to many people. There is urgent need to spread this kind of scientific or technical achievement widely, and the wider it is spread the better. And perhaps the best mode for spreading this is to provide this achievement free of charge, even to proclaim it in newspapers, on the radio, and on television. The public was introduced to the technique of "raising flies in captivity" on the 18 June program "Rural Scientific and Technical Knowledge" from Central Television Broadcasting, which would come under this sort of category.

Opening up technical markets and changing the system of funds allocation is a new important thing in the resolution changing the scientific and technical system. We hope that this kind of system will bring even greater advantages to developing the socialist economy.

In addition, the "Resolution" stipulates that the opening to the outside is "a long term basic policy for China's development of science and technology." According to principles stipulated in the "Resolution," the forms of cooperation between China and technically advanced foreign enterprises, foreign scientific research and educational organizations, and individual scientists and technicians are extremely wide ranging, and all forms of cooperation that can be adopted have nearly all been taken into account, and the advantages brought by that cooperation belong of course to the two or more parties involved. China has come up with far reaching strategic considerations, has produced its own innovative understanding of Marxist theory, and determined that in implementing its bold policy of opening to the outside for both economics and for science and technology, we hope of course that those who cooperate with her will look deeply into the strategic significance of their developing economic and technical exchanges and cooperation with China. The experience of China in recent years has deepened its strategic understanding of itself, has firmed up corresponding policies, and has become bolder when promoting corresponding policies. In recent years, although I have made no special study of China's policies on science and technology, my strategic study of developments in China's overall socialist economy and society has not ceased in 4 years. I feel more and more the importance of strategic study of economic and social development.

I firmly believe that with the support of the Central Committee's policies toward science and technology there is certain to be a great development for China's economy and society.

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NATIONAL DEVELOPMENTS

EFFECTS OF RESTRUCTURING ON CHINESE ACADEMY OF SCIENCES

Beijing ZHONGGUO KEJI LUNTAN [FORUM OF SCIENCE AND TECHNOLOGY IN CHINA] in Chinese No 1, Sep 85 pp 8-10, 34

[Article by Zhou Guangzhao [0719 0342 0664]: "Develop Science and Technology, Promote the National Economy--Some Thoughts on Work at the Chinese Academy of Sciences"]

[Text] I.

Since the 3d Plenum of the 11th Central Committee, China has gone through a new period of restructuring. There has now been 5 years of actual practice for the rural restructuring. After October of last year, we went on to begin a restructuring of the urban economic system, the science and technology system, and the educational system throughout the country. In the science and technology sphere everyone has supported the restructuring. At the center of this reform is an invigoration of the base levels, an arousal of enthusiasm among everyone, a move in the direction of Chinese style socialism, and an implementation of a planned commodity economy. If we truly support this restructuring, then we must naturally analyze its results and analyze its demands for, effects on, and problems for science and technology.

Our current national economy is built on the base of science and technology, and it demands that science and technology be oriented towards the economy, supporting at the same time developments in science and technology at the level permissible by the economy. However, science and technology have their own peculiarities and a relative independence, but modern science and technology long ago left the stage at which a small number could use simple instruments to make discoveries and understand the laws of nature. If for contemporary scientific research there were no accurate instruments, large scale equipment, or a certain number of people to work on things, there would be no way to go on. There must be investment, instruments and equipment, and a certain number of people. The scale and speed at which science develops in a given country is determined by its economy, while at the same time economic development proposes many items of interest for science and technology, stimulating developments in science and technology. Of course, selecting directions and topics for scientific research are not definitely always because of production and economics, but can be for understanding the laws of nature, for understanding those phenomena not yet understood. While

undertaking scientific research, certain directions and topics have no directly applicable goal. Some results also serve the efforts of science and technology themselves. It is because of this relation that the relative independence of science and technology from the economy is generated. But this aspect urges that for science to better serve production should not be slighted because of its effect on the development of all of science and technology. All laws of nature that are understood can be utilized more under certain conditions to form new production forces. But generally speaking, the scale and speed of science and technology is determined by the economy, and if this point is forgotten, scientific research cannot develop well. At the same time, if we ignore its own rules, we will have ignored studies of its regularity, which could become pragmatism, sacrificing the long term benefits of science and production. Strengthening the connections between scientific research and production while handling well the relations between them, is a problem that our workers in science and technology ought to work hard at resolving.

The results of the restructuring of China's economic system will certainly have an even greater effect on developments on science and technology than before. If the enterprises that we have are not in a system that is consistent for 30 years, but rather proceeds from the demands of the marketplace, then their products will certainly be renewed, which will surely produce new requirements for the renovation of science and technology. These requirements, generally speaking, will be certain to produce even greater stimulus and opportunity for developments in science and technology. However, if we do not better understand and make use of these stimuli and opportunities, the Academy of Sciences will not develop. If comrades in the Academy do not bring a fundamental change both ideologically and conceptually and in management methods, then while science and technology throughout the country develops onward many of our institutes might wither.

II.

There are currently various models in the world today by which to develop science and technology. There is the American model, the Soviet model, and there are the models in between, such as the German and Japanese models. Now we want to create a Chinese model. Well then, what a Chinese model would be, what a model would be for the Chinese development of science and technology, requires diligent study, thought, and creativity. In the past we set up the Academy of Sciences by studying the Soviet model. Based on our actual experiences, this model has been as successful as it can be, but has many deficiencies. These are: to a great degree it has been divorced from production. According to the current model, whether or not the Chinese Academy of Sciences can continue to exist is to be doubted. This model can only exist in a system of a completely planned economy under central authority. Today our economic system has begun to change and we cannot go back that this kind of model. In the 1950's and the early part of the 1960's, the Chinese Academy of Sciences made great contributions to our nation, and that was because of special circumstances. On the one hand, our country had a completely planned economy, prescriptively planned, and on the other hand, it was in a situation closed off from the outside, in a situation where no industrial department had a scientific research contingent, but these special

circumstances no longer exist today, nor can they again.

After restructuring the economic system and giving full play to the role of marketplace adjustments, the value of technology will gradually increase because all enterprises will have to constantly renew their products. At the same time, within enterprises and because there are these kinds of requirements, they can completely form their own research contingents. The scientific and technical results in China will unavoidably compete with domestic and foreign products in the marketplace. The majority of applications research and developmental work is done by enterprises or is subsidized by enterprises. Those things that are truly funded by the nation are in that portion of research that is risky, long term, and where the practical significance is not easily seen. Proceeding according to laws of the marketplace, what are national independent research institutes? They are research institutes for things for which enterprises do not have the capabilities and that require national investment, or which require large equipment, or which undertake long term basic research. Other institutes will be replaced by enterprise developed institutes or university developed institutes. This is not a change we are making intentionally, but has been determined by rules of the economic system restructuring. We will want to have a deep understanding regarding this type of problem.

There are advantages peculiar to socialism, which is to say that we must travel in the directions of Chinese models, must fully arouse the enthusiasm of individuals, and organize these things on a new basis, gather together superior capabilities, and develop our science and technology in a planned way. Especially under our backward conditions in China, if we were to use the western models completely and let each unit and individual compete blindly, that would create a great waste of manpower and materials, would add to low quality repetition, and we would always be following behind other people with no alternatives. Therefore, we must find ways to take our own path and take over the advantages of models from other countries, since only in this way can we produce new contributions for the development of Chinese science and technology in the extremely fierce world competition.

III.

Everyone knows that scientific research has administrative levels, while there is also scientific research of different levels in our Academy. We have research work at different administrative levels and we have different disciplines, which are advantages for the Chinese Academy of Sciences, and we have a group that has undergone several decades of scientific research, which has been the most valuable asset for the Academy. How are we to develop our own advantages and utilize our own advantages? This is a problem that ought to be studied at all levels of leadership. One thought is rather clear, which is that future management methods for research at the Academy will be based on the differing natures of that research, managed according to classification, and cannot be done as before, where a "one knife cuts all" approach was used. This requires that each institute will have to independently develop these disciplines of ours according to the nature and characteristics of their own work to serve the national economy.

In the "Resolution" regarding the restructuring of the science and technology system, the CPC Central Committee has said that higher level institutions and the Chinese Academy of Sciences have the responsibility to develop China's basic research and applications research, and that after several statistical surveys, no more than something over 10 percent of the capabilities of the Chinese Academy of Sciences are being used for basic research. We must find ways to allow them to continue research. There are two fundamental goals for work in basic research, one being to represent the Chinese people in making rightful contributions to the development of world science. In another aspect, our basic research goes through a period of time when a certain portion could constitute important applications and exploitable areas, and from that we should train a knowledgeable contingent that in 10 years time could open up new industries. For this purpose we should prepare the efforts of people from different generations. Currently, the average age of those doing basic research is already over 45 years, and it is not realistic to demand that these comrades reach world class levels in a few years. But the work of basic research cannot be interrupted, and requires continuation generation after generation, with generation after generation of effort to allow it to reach world class levels. Therefore, among those comrades doing basic research a number should do foundation work in this regard, uninterruptedly accumulating knowledge, and another portion of comrades who should use their primary efforts to train younger people, and drill them. We want to enhance cooperation with all high level institutions, jointly training for our country a new generation of scientists and technicians to create even better conditions to attract younger people to these research fields, which is a key problem regarding whether or not basic and applications research can make major discoveries. We want to break up this "everything by seniority" practice if we are to attract the most outstanding youth, which is a serious problem regarding whether or not our basic and applications research can continue to develop.

We all hope to build the Chinese Academy of Sciences into a national comprehensive research center for the natural sciences. How will we be able to manage this kind of center? The first step is to set up open laboratories and open institutes, truly facing the needs of all of China and of society. Allow the most outstanding talent in the country to come to the open laboratories. If we were to maintain these open laboratories in our own hands, completely serving the working personnel of the Academy, that could not become a national center for the natural sciences, and would not be accepted by society. Therefore, we hope institutes will break up boundaries between institutes, that they will work toward developing national natural sciences, and allow those of great attainments in these disciplines throughout our country to have even better conditions for exchanging and studying together, to allow them to be the masters of their own affairs.

To better develop the work of basic research we must ensure a certain outlay. Only if basic research is understood by society, is closely linked with society, can it obtain more funds for expenses. Because only when society can understand based on its own experience that by providing funds it can receive even more economic and social results, will it be willing to provide those funds.

IV.

At present, applications and development research have been dealt a strong blow. Things like integrated circuits, large scale computers, color cassettes, magnetic recorders, etc., after so many years of hard work are now in a passive situation in the new trend toward importation. In the past, this contingent assumed many tasks for the nation and has made great contributions, as for example with range equipment, microwave devices, many components on satellites, etc., which was a glorious part of history. But times have changed and we have moved from confinement to openness, and customers can have even greater choices in the marketplace, for which reason we are facing great competition both domestic and foreign. If our technology cannot win out in competition there is the possibility that it will be eliminated. At present, neither our thinking nor our management methods suit this new situation, we have no concept of economic accounting and the marketplace, we have no close-knit organizations and rules for engaging in modern large scale science and technology and production, we have localized, and dispersed efforts all over the place, but we have not formed a strong contingent. Therefore, our applications research and developmental research must be better organized and linked together, it must develop the advantages of the Chinese Academy of Sciences, it must seek to compete, to take on great tasks for the nation. If we remain in a very loose state, we will not be successful in the processes of bidding and competition. At the same time, we must fully utilize our policy of opening to the outside. We cannot passively await imports to shatter our applications and developmental research but must actively use imports to even better stimulate our applications and developmental research. Of course, the starting point of our applications and developmental research ought to stand higher than industrial departments since our goal is not to take over markets already occupied by the industrial departments. Our goal is to use new technology to open up new domestic and foreign markets, especially international markets. To help this nation create technologically intensive industries able to compete on world markets, and at the same time to infiltrate international markets.

As for development work, we ought to strengthen horizontal relations with departments, local areas, and enterprises, and based on our needs to combine our technology with their funds and manpower to form joint operations, several of which have already begun operation. There are only something over 10 percent of those in the Chinese Academy of Sciences truly doing basic research, and there are 30 or 40 percent doing key long-term application projects and large scale projects, with another 30 or 40 percent engaged in developmental research, and they are the bridge that links basic and applications research with the economy. There is a connection between our backward production technology and the fact that we lack this sort of work, and if we do not fully arouse the enthusiasm of these cadres, we will be unable to quickly transform the Chinese Academy of Sciences' results into productive forces.

The Chinese Academy of Sciences has a glorious tradition, and both the state and the people want us to make new contributions to the four modernizations, strengthen scientific research that is geared to the economy and develop science and technology: this is a task that has been handed to us by history.

Under new reform conditions, leaders at all levels must earnestly ponder the situation, take the initiative, lead all personnel into becoming a powerful revolutionary force, proceed in a social direction and seize new victory.

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NATIONAL DEVELOPMENTS

RELATION OF CHINA'S DOMESTIC POLICIES TO THE OUTSIDE

Beijing ZHONGGUO KEJI LUNTAN [FORUM OF SCIENCE AND TECHNOLOGY IN CHINA] in Chinese No 1, Sep 85 pp 4-7

[Article by Song Jian [1345 0256]: "The Chinese Restructuring and Opening to the Outside"]

[Text] A far reaching restructuring of the economic and science and technology systems is just now going on in China. The courage and practicality shown by the party Central Committee and State Council during this reform has won the ardent support of all Chinese people, and has as well attracted the attention of politicians, economists, and scientists around the world. That four special zones, Hainan Island, and 14 coastal cities have opened up to the outside, that the Hong Kong problem has been smoothly resolved, and that a policy of 1 country 2 systems has been adopted have all added new substance and character to the Chinese restructuring. Many intelligent people throughout the world have felt that China's two systems in one country is a most courageous and most attractive pioneering undertaking during the 20th century.

As everyone knows, in more than 3,000 years of history before the industrial age China had created a glorious, resplendent civilization in this world. Those relics everywhere in the Chinese area of influence that have remained to the present, such as the Great Wall, antiquities, and the Qin tombs, still provide a great sense of pride for the Chinese people, and even bring a feeling of awe to the rest of the world. In the most recent half century, China has fallen behind, and although many well meaning people have struggled and sacrificed to change the poor and backward conditions in China, they have unfortunately not yet succeeded. I would rather skip over this quite convoluted stage of history. And that is because whether it be clinging to the glories of the ancestors or immersing ourselves in painful memories, these things could not change what has happened, nor can they be of much help to China's present revitalization.

The American poet, Longfellow, said:

"Our goal
is not happiness, nor is it sorrow
But to struggle
to make each tomorrow
guide us to a distant well-being."

Where China is extremely fortunate is that under the leadership of the Chinese Communist Party liberation was finally won in 1949, and especially since 1978 China has traveled a more correct road. Enormous gains were made from the rural reform, from which has emerged a flourishing, prosperous scene. Urban reform has already begun, immediately producing good momentum. China's 1984 GNP reached $455 billion, up 13 percent over the year before; the gross industrial and agricultural output value was $376.8 billion, up more than 14 percent over the previous year; and the national income was $194.5 billion, up 12 percent over the year before. A growth rate this high has seldom been seen in Chinese history.

I.

Mankind is everlasting but human life is short, and the flourishing of a people will require several generations of continued effort before it can be accomplished. For more than 30 years, and especially in the last few, although China has made great progress, when compared to many developed countries in the world, production and living standards are still quite low. Current per capita output value is only $450, which puts us among countries of the world that have a low income. During the past few decades China's scientists have mastered atomic technology, launched satellites, and synthesized insulin. However, as for the design and production of the necessities of human life and for contributions to the entirety of economic development, this still cannot be considered very great. That it should be this way, one important reason aside from historical, political, and ideological ones is that the economic and scientific and technological systems have formed a kind of model not suitable for the development of social production forces and of science and technology. The primary abuse of this model has been that state control of enterprises and research structures has been stifling, commodity production and the functions of the laws of value and markets have been neglected, egalitarianism in allocation has been serious, etc. All of this has caused a lack of vigor in enterprise and research structures, and workers and scientists have all eaten from the great state pot. Consequently, people have often forgotten that the prosperity of a nation needs the diligent struggle of each individual.

Summing up our own lessons from experience, if we look at the history of the development of mankind's modern civilization, we can gradually realize that, first, a commodity economy is a stage that no country can pass over in advancing toward modernization; second, certain beneficial experiences and accomplishments of every developed country of the world as it develops its economy and science and technology are indexes of advancements in mankind's civilization, and ought to be studied; third, at present, the economy of any country has its national characteristics, and no country can modernize by

living an idyllic confined, self-sufficient life; fourth, building toward modernization must be based upon science and technology, while science and technology can only catch up with the pace of world advances in an environment that is open to the whole world, for confinement signifies eternal backwardness.

To realize the grand goal of an economic quadrupling, China is currently dealing with two matters, one being restructuring, the other opening to the outside. In October of 1984 and March of 1985, the party Central Committee produced two resolutions regarding restructuring of the economic system and restructuring of the scientific and technological system. These two resolutions have made clear the direction of restructuring and outlined the blueprint of restructuring.

In the aspect of reform of the economic system, it is stressed that within a planned commodity economy we must depend upon and use the laws of value, and stimulate the greater development of commodity production and commodity exchange. Only in this way can we realize the modernization of Chinese society and the socialization of production, and can we enrich our country. The Central Committee has resolved that, first, we will change the various ways that the state has too tightly governed enterprises, and will appropriately separate the rights of state run enterprises from management authority, giving enterprises full authority for autonomous management; second, we will reduce the scope of national planning and management, will develop a market economy, will allow as many enterprises as possible to compete in the marketplace, to improve commodity quality through competition, to improve the rate of productivity, to accumulate funds, and to self develop; third, staff wages will be linked to enterprise profits, and they will increase as profits grow; fourth, the responsibilities of government lie in overall control, to use the methods of policy, laws, investment, wages, and tax income to adjust the entire economic system according to statistics for the whole society, to achieve a coordinated development. In summary, the most important measure of the reform is to reduce prescriptive planning, and to selfconsciously rely upon and use the laws of value, fully respecting the role of market adjustments, and forcefully developing a commodity economy.

Price is a measure of commodity production and exchange and a lever for adjusting relations between supply and demand. Principle commodities in the past were given a unified price by the government. As time went on, this non-changing price could not reflect the price of the commodity, nor could it reflect supply and demand relations between society and itself. If we wish to give full play to the role of market structures on economic development, we must reduce inflexible intervention by the government in market prices, and allow the majority of commodity prices to float freely according to market supply and demand relations. Therefore, the first step toward restructuring of the economic system would be a planned and progressive adjustment of prices to establish a reasonable pricing system. Reasonable pricing is the key to the success or failure of restructuring of the entire economic system. This step that the party Central Committee and State Council has taken is to have adopted a very cautious measure, as they have already decided that the 1985 restructuring of the economic system will begin with reform of prices and

wages. The principle is resolute, acting with caution, and certain to succeed.

The wage system is closely connected to commodity prices, and will also be restructured, where the goal is to break up egalitarianism and to encourage that portion of people to get rich first who will create the most wealth for society and help those behind to advance. Wages for staff of state-run enterprises depend upon benefits from enterprises, and will thoroughly implement the principle of compensation for work done. Finally, under the premise of maintaining the leading position of national rights in the economy, we will encourage the development of collective rights and individual rights, and will also develop various modes of economic relations and cooperation among the people, collectives, and individuals, allowing all people the opportunity to be able to create wealth for society.

Facts have already shown that the restructuring of China's economic system was first successful in the rural areas. That agricultural production levels, about which the Chinese people have been anxious for so long, could develop so abruptly in such a short time, has as its primary reason the change in the large and collective people's commune system, where a contract responsibility system based on production was given full scale promotion. The rural economy is just in a transformation toward specialization and commercialization. Farmers have begun to open workshops in villages and townships and run enterprises. The current Chinese countryside is seething with activity, all places are thriving. 1984 output value for small enterprises in rural villages and townships has already reached $46.5 billion, an increase of 24 percent over the previous year. That is more than 40 percent of the national agricultural gross output value.

II.

Vigorous development of a people depends in the final analysis upon progress in science and technology. People are used to seeing science as an exalted goddess, who helps us understand the truth. Technology appears to be her elder son, whose responsibility is in creating wealth for the enjoyment of mankind. Advances in science and technology and economic development is a twin process mutually built up. Modern science and technology has already become a primary motivation for stimulating social modernization.

There are currently more than 9,900 research organizations in China, among which 5,400 are supported by public finance. In the past they have done much work to be proud of, but it cannot be said that they have made great contributions to a flourishing marketplace nor to the development of the social economy. Scientists usually tend toward seeking profound theories and high-level technology, seldom paying much attention to transforming their accomplishments as quickly as possible to social wealth for people to enjoy, and science and technology have become disjointed from production. This was the greatest deficiency in the Chinese scientific and technical system of the past.

The Central Committee has determined that at the same time as the economic restructuring there will also be a restructuring of the scientific and

technical system. The purpose of the reform will be to create the kind of environment that will allow the great majority of research organizations, and especially those research organizations that are closely related to the exploitation of technology, to generate an internal vigor in the economy, a situation that will allow the great majority of researchers to automatically build the economy and pay close attention to the economic results. And society will provide to those units and individuals that make contributions toward a thriving economy even more respect and attention, and the material benefits to scientific and technical personnel will match their contributions.

We will first change the funds allocation system. The government will gradually reduce, and even stop, gratuitous funds allocation to developmental research organizations. Expenses will be obtained through reaching contracts with enterprises, by transferring technology to enterprises, or by performing services for society. For nationally important scientific research projects the methods of public bidding and contracts will be used. There will be a fund system for basic research and applications research, and there will be evaluation by peers and support of the outstanding. As for highly technical development work that is fast changing and somewhat risky, we will establish funds for pioneering work to support it. As for scientific organizations of a social service nature, such as astronomy, time service, meteorology, measurements, information, environmental protection, and hygiene, expenses will still be paid by the government, but in a contractual system.

Second, we will open up the technical marketplace to suit developments in the commodity economy. We will change the past practice where everyone ate from the "large pot," and where findings were distributed gratuitously on orders from higher levels to a compensated contractual system that will enable technical findings to act as funds for investment in enterprises, and which can also be sold on the open market. We will open all doors to the circulation of technology to allow technology to flow uninterrupted from research organizations to enterprises, flowing toward the countryside, spurring on the advancement of enterprises, and stimulating local development.

Third, we will strengthen the introduction of technology and developmental capabilities to enterprises. To solve the problem whereby production technology levels are universally low in Chinese enterprises, we will encourage independent research organizations, and especially developmental technical organizations, to establish joint relations with enterprises on the basis of voluntary mutual benefit, or to join and form one organization. Large scale enterprises will gradually set up their own technical development departments. Middle and small scale enterprises may jointly run shared technology development organizations. As for technical development work undertaken for enterprises, there will be compensation by the state in the aspects of price, taxing, and credit.

Fourth, we will restructure the system that manages scientists and technicians. We will gradually implement an appointment system for them. We will permit them to be reasonably transferred to areas and units that need them more and that can make best use of them, we will encourage them to go to the countryside, to middle and small enterprises, and to develop frontier

areas. We will ensure for them the scholastic freedom to investigate and the freedom of discussion, to allow people to seek the truth without fear.

Comrade Deng Xiaoping has pointed out that "the new economic system ought to be a system beneficial to technical development. The new science and technology system ought to be a system beneficial to economic development. Working along both lines, long standing problems with the separation of technology and economics can possibly be resolved in a better way."

The current restructuring will change modes of activity, organizational structures, and certain ideological viewpoints that people have been accustomed to for many years. This is like a 10,000 ton large ship turning around, and is a very great movement. However, China's restructuring is in keeping with world trends, it fits China's actual situation, is supported by the Chinese people, and is of concern to the people of the world. As long as we resolutely keep to the direction of the reform, energetically lead while going at things quite cautiously, the direction will be forward, measures appropriate, and China's restructuring is certain to be successful.

III.

Advances in science and technology have already made our earth smaller. Communications satellites and modern communications technology allow us to know in a few hours anything that happens anywhere in the world; when necessary, one can go to any place in the world on any given day. Literary persons have said that this world has already become a global village. It is accurate to say that the world of today is an intricately woven large system, and no country can place itself outside of this system. That contemporary technology has reached its current perfection means that every people has made contributions on this behalf. Today, nearly every invention and creation and every developed application for a new technology actually depends upon the joint efforts and cooperation in shared labor by scientists and technicians in every country of the world under differing conditions. Similarly, no new industrial breakthrough nor any great accomplishment in the building of an economy can be made in an environment apart from the world. There is no country or people that can enjoy the full measure of a modern civilization in a confined, self-sufficient idyllic life.

Based on the requirements for building a modern China, the party Central Committee and State Council have decided to implement a policy of opening to the outside. In complete opposition to many years of a tradition of locking up our country, we have opened our doors to the world. Politically, we have implemented two systems in one country, we have economic relations with all friendly countries, and have elicited international cooperation in science and technology. In a word, we are in touch with the world, we are moving toward the world, we are studying all good things in mankind's modern civilization, we have combined these things with the excellent traditions of the Chinese people, we are promoting our own economy, and we are developing science and technology. We truly believe that in the not too distant future the Chinese people will stand together with the other great peoples of the world to make even greater contributions to mankind's civilization.

The policy of opening to the outside that China is carrying out, though it has not been in effect long, has already taken a very great step. From 1980 through 1983, the Chinese national income grew by 32 percent, while imports and exports grew by 57 percent, and overall foreign investment in China is nearly $7 billion. The total number of scientific and technical cooperative projects between China and other countries has reached more than 3,000, and more than 50,000 specialists have gone back and forth. Chinese scientists have joined more than 80 international scientific and technical organizations and scientific groups. There are already nearly 30,000 Chinese graduate and exchange students abroad.

In addition to the 4 areas already opened to the outside, China last year also opened 14 coastal cities that belong to the most essential economic and technically developed regions of China, such as Shanghai, Tianjin, Dalian, and Hainan Island. In time, even more coastal regions from the south to the north will be open to foreign investors as China's modernist construction develops. In the aspects of law, immigration, marriage, and taxes, the government has already or is currently providing for new open policies to be of use to exchanges between the peoples of China and abroad. Relations between the economy of China and the world economy will become closer and closer as the scope of China's openness expands, and the scope of interchanges between the Chinese and other peoples will continue to expand.

Restructuring and opening to the outside are the kernel of China's current policies. If we are to restructure we must open up, and if we are to open up we must restructure. These two governmental policies suit the trends of the world, suit the needs of China in its modern construction, and have already been shown by actual experience and will continue to be shown by actual experience to have great vitality, and cannot be changed by any person. We could not cease if we wanted, we could not stop if we wanted, not could we go back to other directions.

There is a deep friendship between the peoples of China and the other countries of the world. China is willing to develop economic, technical, and trade cooperation with all friendly nations on the basis of equality and mutual benefit. We welcome entrepreneurs from all friendly countries to come to China to run enterprises and other trade organizations, and we welcome scientists and technical specialists from all friendly countries to develop scientific and cultural exchange cooperation of all sorts with China, including coming to China to investigate, teach, and work. And this includes as well cooperative research, development, design, manufacture, etc., with Chinese scientists and technical specialists. In exchange activities of various sorts, they will discover that the ancient people of China have entered a new spring, and they are moving toward the world and toward the future.

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SIMPLE METHOD TO CONSTRUCT CUBIC SPLINE FUNCTION DESCRIBED

Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 567-572

[Article by Tan Fuqi [6223 4395 2601] of the PLA Engineering School in Changsha, manuscript received on 19 May 1982: "A Simple Method To Construct the Cubic Spline Function"]

[Text] Abstract: A simple method to construct the cubic spline function is presented. In addition, relevant problems are discussed. Finally, various treatments for different situations are introduced.

The advantage of using a spline function as an interpolation function is well known. Because it is more difficult to construct a spline function, however, its wide application is limited. We all know that in order to construct a spline function it is necessary to bring simultaneously the nodal function values and boundary conditions into a series of equations. Then, the unknown parameters are determined based on these equations. In a cubic spline function, the second order derivative of every node (i.e., the bending moment of the spline) must be solved to obtain the spline function. This not only is cumbersome to treat mathematically but also wastes computer memory. Furthermore, in some cases it is almost impossible to do. For instance, when we only have simple computation tools (including minicomputers) or when the problem is too trivial to write a program to be calculated on a computer, it is impossible to use a spline function as an interpolation function based on the conventional methods for constructing the spline function. Is it possible to find a simple method to construct a common spline function? The author studied the problem and felt that a section by section iterative construction method could be used to construct the common cubic spline function. It is very effective. The method is introduced in the following.

Let us only consider three neighboring nodes x_{k-1}, x_k, and x_{k+1}. If the functional values are f_{k-1}, f_k, and f_{k+1}, and the second derivative of x_{k-1} is f''_{k-1}. Let us assume that the spline function for this segment is:

$$s(x)=A(x-x_{k-1})(x-x_k)(x-x_{k+1})+B(x-x_{k-1})(x-x_k)+C(x-x_{k-1})+D \qquad (1)$$

By substituting the functional values for x_{k-1}, x_k, and x_{k+1} into equation (1), we can get three equations containing the unknown constants A, B, C, and

D. Another equation can be obtained by plugging the known second order derivative f''_{k-1} at x_{k-1} into the second derivative of $s(x)$. A, B, C, and D can be uniquely determined by these four equations. The results are:

$$\left.\begin{aligned}
&D=f_{k-1},\quad C=\frac{f_k-f_{k-1}}{x_k-x_{k-1}}\\
&B=\left(\frac{f_{k+1}-f_{k-1}}{x_{k+1}-x_{k-1}}-\frac{f_k-f_{k-1}}{x_k-x_{k-1}}\right)\Big/(x_{k+1}-x_k)\\
&A=\left(\frac{f''_{k-1}}{2}-B\right)\Big/(2x_{k-1}-x_k-x_{k+1})
\end{aligned}\right\} \tag{2}$$

A, B, C, and D thus obtained from equation (2) are plugged into equation (1) to obtain the spline function in the segment from x_{k-1} to x_k. If we find the second order derivative of $s(x)$ and then replace $x = x_{k+1}$, then we will be able to determine the second order derivative at x_{k+1} which is expressed as f''_{k+1}. Then

$$f''_{k+1}=2A(2x_{k+1}-x_{k-1}-x_k)+2B \tag{3}$$

where A and B are the A and B determined from equation (2). The value of f''_{k+1} obtained from equation (3) is used as the initial value to construct the spline function in the next segment (i.e., from x_{k+1} to x_{k+2}) by using the same method. Thus the spline function in each segment can be found.

Thus, as long as the function at each node and the initial second derivative are known, the cubic spline function can be derived based on the method mentioned above.

Can this method be used to construct a cubic spline function for any function to be interpolated? Let us discuss this problem in the following.

It must be pointed out that the function thus constructed is not an accurate spline function. Instead, it is an approximate solution of the spline function because the first derivative is not continuous at the nodes. In some cases the value of the first derivative on the left of a node only differs slightly from that on the right. We can treat this spline function as a valid approximation. In other cases, the difference is very large. It is inappropriate to still consider it as an approximation. What are the conditions under which the method is valid? What are the controlling conditions? In the following we will first explain the physical significance and then perform some mathematical analyses. Finally, we will present various treatments for different cases.

As we all know that physically the cubic spline function is equation of the curved elastic spline which passes through every interpolating point. Its direction is determined by the position of each interpolating point and the boundary conditions. Normally, the boundary conditions are required to construct a unique spline function. The segment by segment construction method, however, only needs one boundary condition. The other one is

secondary. As long as the initial boundary condition is given, the corresponding final boundary condition is defined. Thus, there are two possibilities: the method is valid because final value is close to the actual boundary condition and the error is small, or, the method is not valid because the final value disagrees totally with the actual boundary condition and the error is very large. There is no doubt that we must attach certain conditions under which the function constructed meets the requirement. Let us analyze this problem in the following.

From the physical meaning of the spline function we know that as an elastic curve its elastic potential energy must be a minimum, i.e.,

$$\int_{x_0}^{x_N} [s''(x)]^2 dx = \min \tag{4}$$

Let us integrate from x_{k-1} to x_{k+1}.

From equation (1) we get

$$s''(x) = 2[3Ax + B - A(x_{k-1} + x_k + x_{k+1})]$$

By substituting x"(x) into the integral

$$\int_{x_{k-1}}^{x_{k+1}} [s''(x)]^2 dx$$

and by using

$$A = \left(\frac{f''_{k-1}}{2} - B\right) \Big/ (2x_{k-1} - x_k - x_{k+1})$$

we get the following

$$\int_{x_{k-1}}^{x_{k+1}} [s''(x)]^2 dx = 12A^2(x_{k+1} - x_{k-1})^3 + 6A(x_{k+1} - x_{k-1})^2 f''_{k-1} + (x_{k+1} - x_{k-1})(f''_{k-1})^2 \tag{5}$$

Based on equation (5) we know that $\int_{x_{k-1}}^{x_{k+1}} [s''(x)]^2 dx$ is a second order equation of A. According to the charactersitics of such equations, because the coefficient of the A^2 term is positive and $b^2-4ac < 0$, A is always positive. There is a minimum when $A = -b/2a$. Here,

$$a = 12(x_{k+1} - x_{k-1})^3, \quad b = 6(x_{k+1} - x_{k-1})^2 f''_{k-1}, \quad c = (x_{k+1} - x_{k-1})(f''_{k-1})^2$$

In order to minimize $\int_{x_{k-1}}^{x_{k+1}} [s''(x)]^2 dx$

$$A = -\frac{b}{2a} = \frac{-f''_{k-1}}{4(x_{k+1} - x_{k-1})} \tag{6}$$

Based on equation (2), we get

$$A=\left[\frac{f''_{k-1}}{2}-(m_1-m_2)\frac{1}{(x_{k+1}-x_k)}\right]\cdot\frac{1}{2x_{k-1}-x_k-x_{k+1}}$$

where $m_1=(f_{k+1}-f_{k-1})/(x_{k+1}-x_{k-1})$, and $m_2=(f_k-f_{k-1})/(x_k-x_{k-1})$ represent the slopes of LN and LM, respectively (see Figure 1). By substituting A into equation (6) we get

$$\left[\frac{f''_{k-1}}{2}-(m_1-m_2)\frac{1}{x_{k+1}-x_k}\right]\cdot\frac{1}{2x_{k-1}-x_k-x_{k+1}}=\frac{-f''_{k-1}}{4(x_{k+1}-x_{k-1})}$$

After simplification, it becomes

$$m_1-m_2=\frac{(x_{k+1}-x_k)(3x_{k+1}+x_k-4x_{k-1})}{4(x_{k+1}-x_{k-1})}f''_{k-1}$$

or

$$f''_{k-1}=\frac{4(m_1-m_2)(x_{k+1}-x_{k-1})}{(x_{k+1}-x_k)(3x_{k+1}+x_k-4x_{k-1})} \tag{7}$$

Because

$$\frac{(x_{k+1}-x_k)(3x_{k+1}+x_k-4x_{k-1})}{4(x_{k+1}-x_{k-1})}>0$$

$m_1 - m_2$ and f''_{k-1} have the same sign; i.e.,

$$(m_1-m_2)f''_{k-1}>0 \tag{8}$$

It is obvious that when $m_1 - m_2$ and f''_{k-1} satisfy equation (7) the integral $\int_{x_{k-1}}^{x_{k+1}}[s''(x)]^2\,dx$ has a minimum. As we know that a spline function only has to satisfy equation (4), i.e., to take the minimum of the integral over the range from x_0 to x_N. It is not possible to minimize the integral $\int_{x_{k-1}}^{x_{k+1}}[s''(x)]^2\,dx$ in each segment. The cubic spline function thus constructed is only an approximation which cannot possibly take the minimum of $\int_{x_{k-1}}^{x_{k+1}}[s''(x)]^2dx$ in each segment. In reality, we can meet this condition in the first segment by specifying the initial second derivative f''_0. It will not be possible in the second segment because the initial second order derivative in the second segment is derived from the first segment which is already determined. The value of $m_1 - m_2$ in the second segment is determined by the interpolating function which is also known. Obviously, equation (7) cannot be satisfied. The same applies to the rest of the segments. The author, through

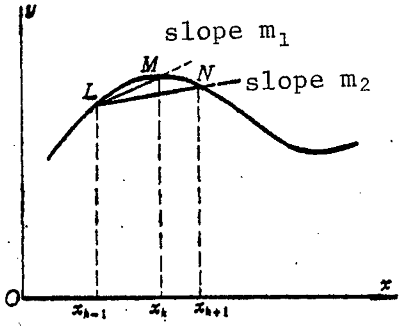

Figure 1.

extensive research, found that the cubic spline function thus constructed is satisfactory in accuracy and totally applicable so long as the initial value is reasonable and equation (8) is not violated in each segment. Providing a reasonable initial value, to a large extent, depends on individual experience. If no experience can be relied upon, then equation (7) can be used to find it. If the precise initial second order derivative is known, it is a very good initial condition. The process can thus be summarized as follows:

1. In the first segment, if the precise initial second order derivative is available, it will be used as the initial second order derivative. If it is not known, then we can determine it by using equation (7). That means

$$f''_0 = \frac{4(m_1 - m_2)(x_2 - x_0)}{(x_2 - x_1)(3x_2 + x_1 - 4x_0)}$$

is used as the initial condition. Or, a suitable f''_0 is chosen by experience.

2. From the second segment on, if the second order derivative of the last node in the preceding segment has the same sign as the $m_1 - m_2$ in the next neighboring segment (i.e., equation (8) is satisfied), then we may continue segment by segment by using the method introduced in this paper. On the contrary, if equation (8) is not satisfied, then a new initial second order derivative value must be given from this segment to proceed with the derivation. For example, if the f''_{k+1} in the segment from x_{k-1} to k_{x+1} is positive and the value of $m_1 - m_2$ in the following segment (i.e., x_{k+1} to x_{k+3}) is negative (i.e., $[(f_{k+3} - f_{k+1})/(x_{k+3} - x_{k+1})] - [(f_{k+2} - f_{k+1})/(x_{k+2} - x_{k+1})]$ is negative, then f''_{k+1} must be redefined according to the method described before to make it satisfy equation (7), i.e.

$$f''_{k+1} = \frac{4(m_1 - m_2)(x_{k+3} - x_{k+1})}{(x_{k+3} - x_{k+2})(3x_{k+3} + x_{k+2} - 4x_{k+1})}$$

where $m_1 = (f_{k+3} - f_{k+1})/(x_{k+3} - x_{k+1})$, $m_2 = (f_{k+2} - f_{k+1})/(x_{k+2} - x_{k+1})$. Then the segment by segment iteration process continues. Obviously, the second order derivative is discontinuous at this node. If the same situation is encountered later, we will treat it accordingly.

Table 1. Comparison of the Cubic Spline Function Derived by Segments to sin10x

x	f_h	f'' Accurate	f'' Calculated	f' Accurate	f' Calculated	f Accurate	f Calculated
0.000000	0.000000	0.000000	0.000000	10.000000	10.050077		
0.008727						0.087156	0.087154
0.017453	0.173648	−17.364818	−17.320810	9.848078	9.848540		
0.026180						0.258819	0.258823
0.034907	0.342020	−34.202014	−34.641619	9.396926	9.395082		
0.043633						0.422618	0.422619
0.052360	0.500000	−50.000000	−49.873218	8.660254	8.660660		
0.061087						0.573576	0.573582
0.069813	0.642788	−64.278761	−65.104818	7.660444	7.657288		
0.078540						0.707107	0.707110
0.087266	0.766044	−76.604444	−76.410178	6.427876	6.428178		
0.095993						0.819152	0.819160
0.104720	0.866025	−86.602540	−87.715539	5.000000	4.995911		
0.113446						0.906308	0.906314
0.122173	0.939693	−93.969262	−93.730988	3.420201	3.420365		
0.130900						0.965926	0.965934
0.139626	0.984808	−98.480775	−99.746437	1.736482	1.731956		
0.148353						0.996195	0.996148
0.157080	1.000000	−100.000000	−99.179116	0.000000	−0.001655		
0.165806						0.996195	0.996126
0.174533	0.984808	−98.480775	−98.611795	−1.736482	−1.727706		
0.183260						0.965926	0.965912
0.191986	0.939693	−93.969262	−93.730988	−3.420201	−3.417061		
0.200713						0.906308	0.906335
0.209440	0.866025	−86.602540	−88.850181	−5.000000	−5.010383		
0.218166						0.819152	0.819181
0.226893	0.766044	−76.604444	−76.410178	−6.427876	−6.431478		
0.235619						0.707107	0.707089
0.244346	0.642788	−64.278761	−63.970176	−7.660444	−7.656528		
0.253073						0.573576	0.573561
0.261799	0.500000	−50.000000	−49.873218	−8.660254	−8.657360		
0.270526						0.422618	0.422641
0.279252	0.342020	−34.202014	−35.776260	−9.396926	−9.404793		
0.287979						0.258819	0.258845
0.296706	0.173648	−17.364818	−17.320810	−9.848078	−9.851840		
0.305433						0.087156	0.087132
0.314159	0.000000	0.000000	1.134641	−10.000000	−9.993091		

As an example, the author calculated sin10x and the results are shown in Table 1. Between 0 to $\pi/10$, sin10x is a half wave which is divided into 18 equal segments. The known functional values f_0, f_1, $\cdots$, f_{18} at points of interpolation are shown in the second column in the table. Because we did not encounter the situation that the second order derivative at the last node in the preceding segment and the $m_1 - m_2$ in the next segment are opposite in sign, therefore, the second order derivative does not have any discontinuities. The first f" value in the table is given. The rest of them are calculated which are very close to the actual values. (The initial value is accurate, i.e., $f''_0 = 0$.) The values of f' are also calculated by using this method. (At each point of division the value of f' on the left is slightly different from that on the right. The difference, however, is very small. They are all very close to the actual values. The values on the left are tabulated in the table.) The column f shows the interpolated values between two nodes. We can see that it is fairly accurate.

It is easy to realize that this method is more suited for the interpolation of slowly varying functions. Its error may be relatively large for rapidly varying functions (especially when the second order derivative changes directions) because it will frequently encounter the situation in which the second order derivative of the preceding segment and the $m_1 - m_2$ in the next segment have opposite signs. Consequently, we will have to reassign a new initial second order derivative, leading to more second order derivative discontinuities. The entire curve is no longer as smooth. An initial second order derivative may be assigned to each segment based on equation (7). In this case the first and second order derivatives are not continuous at the nodes and the cubic spline function is sectional.

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APPLIED SCIENCES

MODEL FOR BOUNDARY INTEGRAL EQUATION IN SOLID MECHANICS

Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 531-540

[Article by Wang Xingfeng [3769 5281 7364] of Tongqi University and Wang Xingfa [3769 5281 4099] of Beijing Institute of Technology, recommended by Qian Weichang [6929 0251 7022], manuscript received on 27 December 1984: "A Computational Model of Boundary Integral Equation in Solid Mechanics"]

[Text] Abstract: This paper contains two aspects: 1) establishing a computational model for boundary integral equations in solid mechanics and 2) using this model to calculate two solid mechanics problems.

1. Introduction

Boundary integral equation is an important technique in modern numerical methods. Because of its obvious accomplishments in complicated engineering problems,[1-8] this method has received wide attention in the world. Relatively, this numerical method is not extensively studied in China. We hope that this paper will promote the use of boundary integral method in engineering practices.

Rizzo[9] and Cruse[10] first discretized partial differential equations into boundary integral equations. The initial equations they set up, however, are very rough. The accuracy of this method was later improved by Cruse[11] and other scholars.[12] Recently, some scholars[13,14] combined boundary integral equation method with finite element technique to solve some complicated engineering problems.

In this paper we use the significance of the δ function structure in the basic solution of the Dirichlet or Neumann problems to obtain a singular integral equation through Green equation. Based on that, this basic solution satisfies the Liepshi α exponent ($0\leqslant\alpha\leqslant1$) condition on the boundary, this singular integral equation is expanded to the practical stage. In this paper the boundary integral of a biharmonic equation and a Navier equilibrium equation is presented. In addition, the stress expression in this computation model is also derived. Finally, this model is used to calculate two solid mechanics problems.

2. Computation Model

Let us choose the following constant coefficient m^{th} order differential equations:

$$P(\partial)u = \sum a_\alpha \partial^\alpha u = 0 \tag{2.1}$$

If $P(\partial)E = \delta$, we call E the basic solution of the differential equation $P(\partial)u = 0$ where δ is a Dirac function. If E is the basic solution of $P(\partial)u = 0$, then

$$P(\partial)u = f, \ u = E*f \tag{2.2}$$

where $E*f = \int_{-\infty}^{+\infty} E(x-y)f(y)dy$

Let us assume that there is a two-dimensional body A and we are looking for the function ϕ which satisfies the Laplace equation.

$$\nabla^2\phi = 0 \qquad (\phi \in D) \tag{2.3}$$

$$\phi = f \text{或} \frac{\partial \phi}{\partial n} = g \qquad (\phi \in c) \tag{2.4}$$

where n is the normal vector at any point c on the boundary, f and g are boundary functions, f or g may also be an unknown. This is a Dirichlet or Neumann problem such as in elastic torsion and ideal flow.

The δ function basic solution (2.3) is used. According to Figure 1

$$\lim_{\varepsilon \to 0} P_\varepsilon(x) = \delta(x) = \begin{cases} \infty & x = 0 \\ 0 & x \neq 0 \end{cases}$$

If f(x) is continuous at x = 0, then

$$\int_{-\infty}^{+\infty} f(x)\delta(x)dx = f(0)$$

If $\delta(x)$ is moved from the origin to x_0 and f(x) is continuous at $x = x_0$, then

$$\int_{-\infty}^{+\infty} \delta(x-x_0)f(x)dx = f(x_0) \tag{2.5}$$

Now, let us solve the special solution ω of the following equation

$$\nabla^2\phi = \delta(x-x_0, \ y-y_0) \tag{2.6}$$

in spite of the fact that φ is the basic solution of (2.3). Let us use a polar coordinate using M_0 as the origin. A circle D_s is defined by using a small quantity ε as the radius and c_s as the boundary. When $r > 0$ (r is the distance between M_0 and M in the region D), φ should satisfy the following equations in the symmetric case.

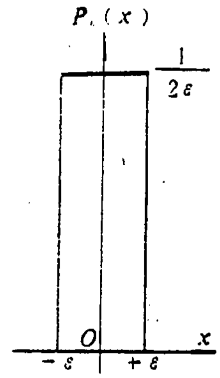

Figure 1. The δ Function

$$\left(\frac{\partial^2}{\partial r^2}+\frac{1}{r}\ \frac{\partial}{\partial r}\right)\varphi=0$$

$$\varphi=C_1+C_2\ln r$$

If Green's first equation is applied in D_s, then

$$\iint_{D_\varepsilon}\Delta\varphi d\sigma=\int_{c_\varepsilon}\frac{\partial\varphi}{\partial n}ds$$

$$\int_{c_\varepsilon}\frac{\partial\varphi}{\partial n}ds=\iint_{D_\varepsilon}\delta(x-x_0,y-y_0)\,d\sigma=1$$

$$\int_{c_\varepsilon}\frac{\partial\varphi}{\partial n}ds=-\int_0^{2\pi}\frac{\partial\varphi}{\partial r}\cdot rd\theta=-2\pi C_2$$

$C_2 = -\frac{1}{2\pi}$ choose $C_1 = 0$, we get $\varphi = -\frac{1}{2\pi}\ln r$

where $\Delta = \nabla^2$.

$$\varphi = -\ln r \tag{2.7}$$

is the basic solution of (2.3).

If the basic solution (2.7) is plugged into the second Green formula (2.8)

$$\iint_{D-D_\varepsilon}(u\Delta V-V\Delta u)\,d\sigma=\int_{c+c_\varepsilon}\left(u\,\frac{\partial V}{\partial n}-V\ \frac{\partial u}{\partial n}\right)ds \tag{2.8}$$

Because M_0 is a discontinuity point, therefore, equation (2.8) is applied in the region $D-D_s$. Let us choose V as the basic solution, i.e. $V = \ln r$,

$$\iint_{D-D_\varepsilon}[u\Delta(-\ln r)+\ln r\cdot\Delta u]d\sigma$$

$$=\int_{c+c_\varepsilon}\left[u\frac{\partial}{\partial n}(-\ln r)+\ln r\,\frac{\partial u}{\partial n}\right]ds \tag{2.9}$$

where c_s is the boundary of D_s.

$$\int_{c_\varepsilon} u\,\frac{\partial}{\partial n}(-\ln r)\,ds=2\pi\cdot u^* \tag{2.10}$$

where u^* is the median value of u(M) on c_s.

$$\int_{c_\varepsilon} \ln r\,\frac{\partial u}{\partial n}ds=2\pi\cdot\varepsilon\cdot\ln\varepsilon\cdot\left(\frac{\partial u}{\partial n}\right)^* \tag{2.11}$$

where $(\partial u/\partial n)^*$ is the median value of the normal derivative $\partial u(M)/\partial n$ on c_s.

By substituting equations (2.10) and (2.11) into (2.9), when $\varepsilon\to 0$, we get the following by taking the limits on both sides.

$$2\pi u(M_0)=\int_c\left[u\frac{\partial}{\partial n}\ln r-\ln r\,\frac{\partial u}{\partial n}\right]ds+\iint_D\ln r\cdot\Delta u d\sigma \tag{2.12}$$

If $u = \phi$ is a harmonic function, we will get a two-dimensional boundary integral equation.

$$\phi(M_0)=\frac{1}{2\pi}\int_c\left[[\phi(M)\frac{\partial}{\partial n}\ln r_{M_0M}-\ln r_{M_0M}\frac{\partial\phi(M)}{\partial n}\right]ds_M \tag{2.13}$$

Thus, a Dirichlet or Neumann problem can be converted into a boundary integral equation (2.13). If the function ϕ on the boundary c, $\phi(M)$, and its normal derivative $\partial\phi(M)/\partial n$ are known, then the unknown function $\phi(M_0)$ at any point M_0 in D can be determined by equation (2.13).

The linear elastic biharmonic equation is

$$\nabla^4\varphi=0 \tag{2.14}$$

Equation (2.14) is one of the basic equations in solid mechanics. ω is a function of stress. The basic solution of equation (2.14) is $r^2\ln r$.

Let $\quad \nabla^4\varphi=\nabla^2\phi=0 \qquad (2.15)$

then $\quad \phi=\nabla^2\varphi=\nabla^2 r^2\ln r \qquad (2.16)$

In analogy to the above derivation, equation (2.16) is plugged into the second Green function.

$$\iint_{D-D_\varepsilon}[u\Delta\cdot(\Delta r^2\ln r)-\Delta(r^2\ln r)\Delta u]d\sigma$$

$$=\int_{c+c_\varepsilon}\left[u\frac{\partial}{\partial n}(\Delta r^2\ln r)-\Delta(r^2\ln r)\,\frac{\partial u}{\partial n}\right]ds_M \tag{2.17}$$

When $\varepsilon \to 0$, equation (2.17) becomes

$$\left.\begin{aligned}
&\int_{c_\varepsilon} u\frac{\partial}{\partial n}(4\ln r+4)rd\theta = -8\pi u^* \\
&\int_{c_\varepsilon} \Delta r^2 \ln r \frac{\partial u}{\partial n} ds = -\int_0^{2\pi}(4\ln r+4)\frac{\partial u}{\partial r}\cdot rd\theta \to 0 \\
&\iint_{D_\varepsilon}[u\Delta(\Delta r^2\ln r)-\Delta(r^2\ln r)\Delta u]\,d\sigma \to 0
\end{aligned}\right\} \tag{2.18}$$

Let u = φ, then

$$\begin{aligned}
&\iint_D[\Delta\phi(r^2\ln r)-(\Delta r^2\ln r)\cdot\phi]d\sigma \\
&\quad =\int_\sigma\left[(r^2\ln r)\frac{\partial\phi}{\partial n}-\phi\frac{\partial}{\partial n}(r^2\ln r)\right]ds_M
\end{aligned} \tag{2.19}$$

By substituting equations (2.18) and (2.19) into (2.17), we obtain a series of boundary integral equations corresponding to the biharmonic equation (2.14):

$$\left.\begin{aligned}
\varphi(M_0) &= \frac{1}{8\pi}\int_\sigma\Big[\varphi(M)\frac{\partial}{\partial n}\Delta(r^2\ln r)-\Delta(r^2\ln r)-\frac{\partial\varphi(M)}{\partial n} \\
&\qquad +\phi(M)\frac{\partial}{\partial n}(r^2\ln r)-(r^2\ln r)\frac{\partial\phi(M)}{\partial n}\Big]ds_M \\
\phi(M_0) &= \frac{1}{2\pi}\int_\sigma\left[\phi(M)\frac{\partial}{\partial n}\ln r-\frac{\partial\phi(M)}{\partial n}\cdot\ln r\right]ds_M
\end{aligned}\right\} \tag{2.20}$$

In analogy, we can also derive the boundary integral equation for a three-dimensional Laplace equation.

$$\phi(M_0)=\frac{1}{4\pi}\iint_\Sigma\left[\frac{1}{r}\frac{\partial\phi(M)}{\partial n}-\phi(M)\frac{\partial}{\partial n}\left(\frac{1}{r}\right)\right]d\sigma_M \tag{2.21}$$

where Σ is the boundary of a three-dimensional body B; and the boundary integral equation for a Navier equation

$$u_i(M_0)=\int_\sigma[U_{ij}P_j(M)-T_{ij}u_j(M)]ds_M \qquad (i,j=1,2) \tag{2.22}$$

If the force $P_j(M)$ and displacement $u_j(M)$ on the boundary c are known, then the displacement $u_i(M_0)$ at any point in the body can be obtained based on equation (2.22). In equation (2.22), U_{ij} and T_{ij} are second order tensors.

$$U_{ij}=C_1(\delta_{ij}C_2\ln r-r_{,i}r_{,j})$$

$$T_{ij}=\frac{C_3}{r}\left[\frac{\partial r}{\partial n}(\delta_{ij}C_4+2r_{,i}r_{,j})+C_4(r_{,j}n_i-r_{,i}n_j)\right]$$

where

$$C_1=-\frac{1}{8\pi G(1-\mu)},\quad C_2=3-4\mu,\quad C_3=-\frac{1}{4\pi(1-\mu)},\quad C_4=1-2\mu$$

u is the Poison ratio and G is the shear modulus. The comma in the subscript represents the partial derivative with respect to the coordinate. n is the unit vector normal to the body boundary.

The boundary conditions ϕ and $\partial\phi/\partial n$ or the force and displacement on the boundary are known at various times. The following complex variable theory is used:

Let us assume that c is a smooth enclosed curve and (j) is on c. Furthermore, it obeys the Liepshi condition with an exponent α, $0\leqslant\alpha\leqslant 1$. When a point z approaches a point t from inside c, the Cruse integral

$$F(z)=\frac{1}{2\pi i}\int_c \frac{\varphi(j)}{j-z}dj \tag{2.23}$$

approaches the following limit:

$$F(t)=\frac{1}{2}\varphi(t)+\frac{1}{2\pi i}\int_c \frac{\varphi(j)}{j-t}dj \tag{2.24}$$

The basic solution in this paper satisfies the Liepshi condition. Hence, when $M_0 \rightarrow P$ (M is a point inside the region and P is a boundary point), based on equation (2.24), equations (2.13), (2.20), (2.21), and (2.22) become

$$\phi(P)=\frac{1}{\pi}\int_c\left[\phi(M)\frac{\partial}{\partial n}\ln r_{PM}-\ln r_{PM}\frac{\partial\phi(M)}{\partial n}\right]ds_M \tag{2.25}$$

$$\left.\begin{aligned}\varphi(P)=&\frac{1}{4\pi}\int_c\Big[\varphi(M)\frac{\partial}{\partial n}(\nabla^2 r_{PM}^2\ln r_{PM})\\&-\frac{\partial\varphi(M)}{\partial n}(\nabla^2 r_{PM}^2\ln r_{PM})+\phi(M)\frac{\partial r_{PM}^2\ln r_{PM}}{\partial n}\\&-\frac{\partial\phi(M)}{\partial n}(r_{PM}^2\ln r_{PM})\Big]ds_M\\\phi(P)=&\frac{1}{\pi}\int_c\left[\phi(M)\frac{\partial}{\partial n}\ln r_{PM}-\frac{\partial\phi(M)}{\partial n}\cdot\ln r_{PM}\right]ds_M\end{aligned}\right\} \tag{2.26}$$

$$\phi(P)=\frac{1}{2\pi}\iint_\Sigma\left[\frac{1}{r_{PM}}\frac{\partial\phi(M)}{\partial n}-\phi(M)\frac{\partial}{\partial n}\left(\frac{1}{r_{PM}}\right)\right]ds_M \tag{2.27}$$

$$u_i(P)=2\int_c[U_{ij}P_j(M)-T_{ij}u_j(M)]ds_M \qquad (i,j=1,2) \tag{2.28}$$

where r_{PM} is the distance between M and the point P on the boundary c. Equations (2.25) - (2.28) can be used to solve all boundary conditions. By substituting these boundary conditions into equations (2.13), (2.20), (2.21), and (2.22) we can solve the unknown stress or displacement at any point M_0 in the body.

3. Numerical Solution

The integral equations in this paper are generally singular. The program to compute their numerical solutions is as follows:

(1) The boundary is divided into unequal discrete regions to simulate boundary conditions such as force and displacement as well as the boundary itself by section.

(2) Singularity equations are converted into algebraic equations by section.

(3) The unknowns are solved from the algebraic equations.

Let us list the algebraic equations for the boundary integral equation (2.26) of the biharmonic equation.

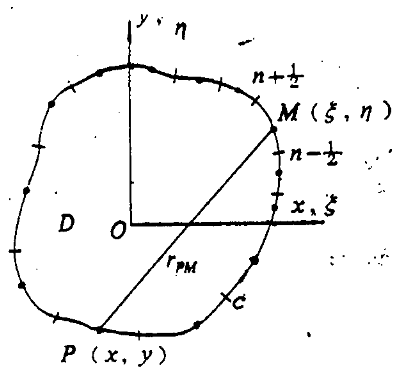

Figure 2. Boundary Division

The boundary is divided into n unequal sections as shown in Figure 2. The number on the direction label increases with c. The center of each region, M, is a nodal point. Let us assume that $\phi(x,y)$ and $\partial\phi(x,y)/\partial n$ are constant in each region. In addition, they are equal to their nodal point values $\phi(M)$ and $\partial\phi(M)/\partial n$. Through such boundary simulations, it is possible to use the 2n equations (3.1) with unknowns $\phi(M)$ and $\partial\phi(M)/\partial n$ to replace equation (2.26).

$$\left.\begin{aligned} \pi\phi(P) &= \sum_{M=1}^{n}\left(a_{PM}\phi(M) - b_{PM}\frac{\partial\phi(M)}{\partial n}\right) \\ 4\pi\varphi(P) &= \sum_{M=1}^{n}\left(c_{PM}\phi(M) - d_{PM}\frac{\partial\phi(M)}{\partial n} + e_{PM}\varphi(M) - f_{PM}\frac{\partial\varphi(M)}{\partial n}\right) \end{aligned}\right\} \tag{3.1}$$

where P = 1, 2, ···, n. In matrix form

$$\begin{pmatrix} [a_{PM} - I\pi] - [b_{PM}] \\ [c_{PM}] - [d_{PM}] \end{pmatrix}\begin{pmatrix} [\phi(M)] \\ \dfrac{\partial\phi(M)}{\partial n} \end{pmatrix} = \begin{pmatrix} [0] & [0] \\ [4\pi I - e_{PM}] & [f_{PM}] \end{pmatrix}\begin{pmatrix} [\varphi(M)] \\ \left[\dfrac{\partial\varphi(M)}{\partial n}\right] \end{pmatrix} \tag{3.2}$$

where I is a unit matrix. The coefficients are

$$\left.\begin{aligned} a_{PM}&=\int_M \frac{\partial}{\partial n}\ln r_{PM}\,ds_M, \quad b_{PM}=\int_M \ln r_{PM}\,ds_M \\ c_{PM}&=\int_M \frac{\partial}{\partial n} r_{PM}^2\ln r_{PM}\,ds_M, \quad d_{PM}=\int_M r_{PM}^2 \ln r_{PM}\,ds_M \\ e_{PM}&=\int_M \frac{\partial}{\partial n}\nabla^2 r_{PM}^2\ln r_{PM}\,ds_M, \quad f_{PM}=\int_M \nabla^2 r_{PM}^2\ln r_{PM}\,ds_M \end{aligned}\right\} \tag{3.3}$$

Hence, the problem is simplified to solving the following matrix equation.

$$B\{X\} = \{R\} \tag{3.4}$$

where B is a 2n x 2n matrix. {X} and {R} are 2n x 1 matrices. The unknown $\phi(M)$ or $\partial\phi(M)/\partial n$ on the boundary c can be determined based on equation (3.4). By substituting it into the first equation of (2.20) we can get $\varphi(M_0)$. Based on $\varphi(M_0)$ we will be able to get the stress at any point M_0 in the body.

$$\left.\begin{aligned} 8\pi\sigma_x(M_0) &= \sum_{M=1}^{n}\Big[A_{M_0M}\,\varphi(M) - B_{M_0M}\frac{\partial\varphi(M)}{\partial n} \\ &\quad + C_{M_0M}\,\phi(M) - D_{M_0M}\frac{\partial\phi(M)}{\partial n}\Big] \\ 8\pi\sigma_y(M_0) &= \sum_{M=1}^{n}\Big[E_{M_0M}\,\varphi(M) - F_{M_0M}\frac{\partial\varphi(M)}{\partial n} \\ &\quad + G_{M_0M}\phi(M) - H_{M_0M}\frac{\partial\phi(M)}{\partial n}\Big] \\ 8\pi\tau_{xy}(M_0) &= \sum_{M=1}^{n}\Big[-I_{M_0M}\varphi(M) + J_{M_0M}\varphi(M) \\ &\quad - K_{M_0M}\phi(M) + L_{M_0M}\frac{\partial\phi(M)}{\partial n}\Big] \end{aligned}\right\} \tag{3.5}$$

where the coefficients are

$$A_{M_0M} = \frac{\partial^2}{\partial y^2}(e_{M_0M}), \quad B_{M_0M} = \frac{\partial^2}{\partial y^2}(f_{M_0M})$$

$$C_{M_0M} = \frac{\partial^2}{\partial y^2}(c_{M_0M}), \quad D_{M_0M} = \frac{\partial^2}{\partial y^2}(d_{M_0M})$$

$$E_{M_0M} = \frac{\partial^2}{\partial x^2}(e_{M_0M}), \quad F_{M_0M} = \frac{\partial^2}{\partial x^2}(f_{M_0M})$$

$$G_{M_0M} = \frac{\partial^2}{\partial x^2}(c_{M_0M}), \quad H_{M_0M} = \frac{\partial^2}{\partial x^2}(d_{M_0M})$$

$$I_{M_0M} = \frac{\partial^2}{\partial x\partial y}(e_{M_0M}), \quad J_{M_0M} = \frac{\partial^2}{\partial x\partial y}(f_{M_0M})$$

$$K_{M_0M} = \frac{\partial^2}{\partial x\partial y}(c_{M_0M}), \quad L_{M_0M} = \frac{\partial^2}{\partial x\partial y}(d_{M_0M})$$

4. Applications

Let us give some examples of the applications of this method. The first example is a plate with a crack (see Figure 3). Figure 4 shows its boundary division in which the external force is P = 2. All units are rendered dimensionless. Boundary integral equations (2.20), (2.26), and (3.2) were used to write a computer program to calculate the type I stress strength factor K_I in linear elastic fracture mechanics. The result is

$$K_I = 4.95$$

The published result is K = 5.01[15] (which has an 0.5 percent error). It shows that the boundary integral method is very accurate in calculating K_I.

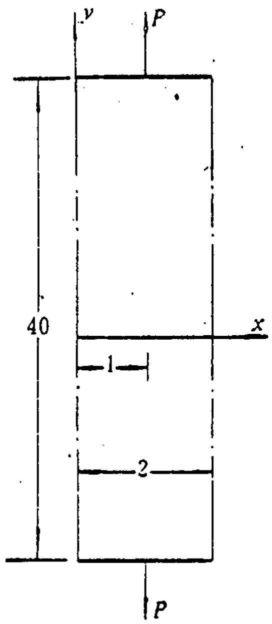

Figure 3. A Cracked Plate

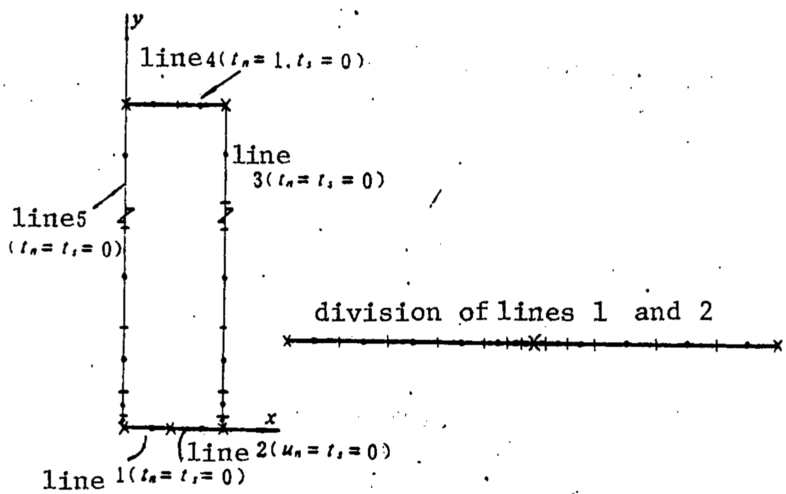

Figure 4. The Boundary Division

The second example is the St. Venant torsion problem.[16]

According to the theory of elasticity:

$$\tau_{xz} = -G\left(\frac{\partial\varphi}{\partial y} + ky\right), \quad \tau_{yz} = G\left(\frac{\partial\varphi}{\partial x} + kx\right) \tag{4.1}$$

where G is the shear modulus and k is a constant.

$$\left.\begin{array}{ll} \nabla^2\varphi = 0 & (\varphi \in B) \\ \varphi = -\frac{1}{2}k(x^2+y^2) & (\varphi \in \partial B) \end{array}\right\} \tag{4.2}$$

Let $\phi = -\frac{2}{k}\varphi$, then equation (4.2) becomes:

$$\nabla^2\phi = 0 \quad \text{in region B}$$

$$\phi = x^2 + y^2 \quad \text{on boundary B.}$$

Let us assume that a rectangular bar with a cross-section of 20 x 32 cm^2 is under a torque M_T, as shown in Figure 5. The boundary integral equations (2.13) and (2.25) are used to solve the problem. A coordinate system is set up using the center of the rectangular cross-section as the origin. The boundary is divided into eight regions.

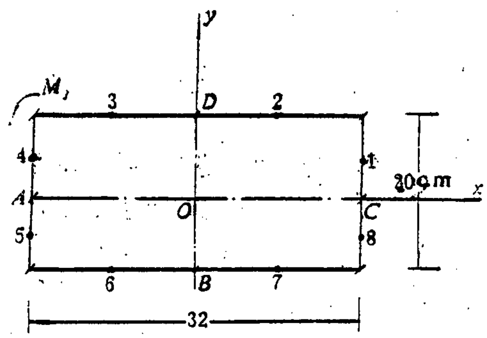

Figure 5. Boundary Division of a Twisted Bar

According to symmetry, there are only two boundary unknowns, $\partial\phi_1/\partial n$ and $\partial\phi_2/\partial n$. The coefficients determined by this method are:

$a_{11}=0$	$a_{12}=1.268$	$a_{13}=0.148$	$a_{14}=0.310$
$a_{15}=0.283$	$a_{16}=0.314$	$a_{17}=0.818$	$a_{18}=0$
$a_{21}=0.896$	$a_{22}=0$	$a_{23}=0$	$a_{24}=0.395$
$a_{25}=0.300$	$a_{26}=0.495$	$a_{27}=0.761$	$a_{28}=0.294$
$b_{11}=6.094$	$b_{12}=35.449$	$b_{13}=50.918$	$b_{14}=34.698$
$b_{15}=35.154$	$b_{16}=53.399$	$b_{17}=45.677$	$b_{18}=22.546$
$b_{21}=22.677$	$b_{22}=17.264$	$b_{23}=43.592$	$b_{24}=32.055$
$b_{25}=33.453$	$b_{26}=51.957$	$b_{27}=48.328$	$b_{28}=28.255$

On the boundary,

$$\phi_1=\phi_4=\phi_5=\phi_8=281,\quad \phi_2=\phi_3=\phi_6=\phi_7=164$$

$$\frac{\partial\phi_1}{\partial n}=\frac{\partial\phi_4}{\partial n}=\frac{\partial\phi_5}{\partial n}=\frac{\partial\phi_8}{\partial n},\quad \frac{\partial\phi_2}{\partial n}=\frac{\partial\phi_3}{\partial n}=\frac{\partial\phi_6}{\partial n}=\frac{\partial\phi_7}{\partial n}$$

Equation (2.25) in this paper is the first equation of (3.1).

$$98.492\frac{\partial\phi_1}{\partial n}+186.343\frac{\partial\phi_2}{\partial n}=-298.283,\quad 116.440\frac{\partial\phi_1}{\partial n}+161.41\frac{\partial\phi_2}{\partial n}=220.448$$

We get the following solution:

$$\frac{\partial\phi_1}{\partial n}=15.298,\quad \frac{\partial\phi_2}{\partial n}=-9.690 \tag{4.4}$$

By substituting equation (4.4) into (2.13), we get the following discrete equation:

$$\phi(M_0)=-\frac{1}{2\pi}\sum_{M=1}^{8}\left[\phi(M)\int_M \frac{\partial}{\partial n}(\ln r_{M_0M})ds_M-\frac{\partial\phi(M)}{\partial n}\int_M \ln r_{M_0M}ds_M\right]$$

where the coordinates of M_0 is x,y. The results of the boundary integral method are obtained based on equation (4.1).

At O (0,0): $\tau_{xz}=0,\ \tau_{yz}=0$

At B (0,-10): $(\tau_{xz})_{max}=13.237Gk,\ \tau_{yz}=0$

The results obtained based on the theory of elasticity by Timoshenko[16] are:

At O (0,0): $\tau_{xz}=0,\ \tau_{yz}=0$

At B (0,-10): $(\tau_{xz})_{max}=17.38Gk,\ (\tau_{yz})=0$

Timoshenko employed a series method to obtain this approximate solution. It requires over 10 hours to calculate by hand. The computation load is very small by using this method. Its accuracy is easy to control.

5. Discussion

The core integral of the boundary integral equation is physically significant. The solution of the linear partial differential equation is usually a result of continuously distributed quantities. Hence, the physical significance of the core integral is an effect created by concentrated quantities. This computation method requires that the boundary be piecewise smooth and arbitrary in shape. The center of the problem is to determine the core integral. If a more effective mathematical technique can be used to construct the core integral, it will be more widely used in practice. Boundary integral equation is a modern numerical technique to be further explored.

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APPLIED SCIENCES

PASSIVE LOCATION, TRACKING FOR MOVING EMITTERS

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 13 No 2, Mar 85 pp 74-79

[Article by Sun Zhongkang [1327 0112 1660] and Zhang Peng [1728 2590], Changsha Institute of Technology, Hunan; received in August 1983, finalized in October 1984]

[Text] Abstract: Passive location and tracking method using multiple measuring stations is discussed for a moving target carrying an active emitter. Weighted least square estimation for target location and Kalman filtering for tracking and prediction are used in such a passive location system. Simulation results show that it is an efficient method for emitter location. The location accuracy depends on the number, measuring accuracy and geometry of the stations and the moving emitter trajectories.

To prevent defense penetration, more and more aircraft and flying objects are now equipped with active jamming emitters. Although such jamming emitters defeat the normal task of radars, at the same time they expose themselves. Hence, this paper explores the feasibility of location and tracking.

I. Principle of Location and Estimation Method

In receiving the radio jamming signal from an airborne emitter, radars can normally detect the direction angle (i.e., bearing angle β and angle of elevation ε). Assuming that the space position of the target emitter and the radar are, respectively:

$$x_T=(x_T \ y_T \ z_T)^T \tag{1}$$

$$x_1=(x_1 \ y_1 \ z_1)^T \tag{2}$$

then the relationship of the measured bearing angle relative to target position, and the radar station are:

$$\begin{aligned} \mathrm{tg}\,\beta_1&=(x_T-x_1)/(y_T-y_1) \\ \mathrm{tg}\,\varepsilon_1&=(z_T-z_1)/\sqrt{(x_T-x_1)^2+(y_T-y_1)^2} \end{aligned} \tag{3}$$

As shown in Figure 1, in order to determine the target's three coordinates x_T, y_T, z_T, it can be seen that at the least data of three direction angles (one being the angle of elevation) are required. Because of the relatively large error of angle measuring obtained through radars, it is generally desirable to obtain more data so that a higher location accuracy can be achieved.

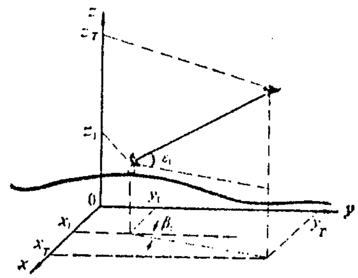


Figure 1. Relationship of Direction Angle Relative to Target Position and Radar Station

1. Weighted least square estimation

Let us assume that there are N radars surveying a target emitter, and the target's bearing angle β_i and elevation angle ε_i measured by the i^{th} radar are:

$$\beta_i = \mathrm{tg}^{-1}\frac{x_T - x_i}{y_T - y_i}, \quad \varepsilon_i = \mathrm{tg}^{-1}\frac{z_T - z_i}{\sqrt{(x_T - x_i)^2 + (y_T - y_i)^2}} \tag{4}$$

where x_i, y_i, z_i are the three coordinates of the i^{th} radar. Assuming the rough estimate on the target position is

$$x_0 = (x_0 \quad y_0 \quad z_0)^T$$

and carrying out the Taylor series, on the rough estimate x_0 using β_i, ε_i, and eliminating high order terms, we obtain

$$\begin{cases} \beta_i = \beta_{0i} + a_{xi}\delta x + a_{yi}\delta y + a_{zi}\delta z \\ \varepsilon_i = \varepsilon_{0i} + b_{xi}\delta x + b_{yi}\delta y + b_{zi}\delta z, \qquad i = 1,\ 2,\ \cdots\cdots,\ N \end{cases} \tag{5}$$

where β_{0i}, ε_{0i} are, respectively, the rough estimates of target location corresponding to the bearing angle and the elevation angle from the i^{th} radar, then

$$\begin{aligned} a_{xi} &= \left.\frac{\partial \beta_i}{\partial x_T}\right|_{x_T = x_0} = \frac{y_0 - y_i}{R^2_{h0i}}, & b_{xi} &= \left.\frac{\partial \varepsilon_i}{\partial x_T}\right|_{x_T = x_0} = -\frac{(x_0 - x_i)(y_0 - y_i)}{R_{h0i}R^2_{0i}} \\ a_{yi} &= \left.\frac{\partial \beta_i}{\partial y_T}\right|_{x_T = x_0} = -\frac{x_0 - x_i}{R_{h}{}^2{}_{0i}}, & b_{yi} &= \left.\frac{\partial \varepsilon_i}{\partial y_T}\right|_{x_T = x_0} = -\frac{(y_0 - y_i)(z_0 - z_i)}{R_{h0i}R^2_{0i}} \\ a_{zi} &= \left.\frac{\partial \beta_i}{\partial z_T}\right|_{x_T = x_0} = 0, & b_{zi} &= \left.\frac{\partial \varepsilon_i}{\partial z_T}\right|_{x_T = x_0} = \frac{R_{h0i}}{R_0{}^2{}_i} \end{aligned} \tag{6}$$

in which:

$$R_{h0i} = \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2}, \quad R_{0i} = \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2 + (z_0 - z_i)^2} \tag{7}$$

and δx, δy, δz are, respectively, the deviation between target location and the corresponding rough estimate in the three coordinates. Now written in short form as

$$\delta x = [\delta x \ \ \delta y \ \ \delta z]^T = x_T - x_0$$

$$H_w = \begin{bmatrix} a_{x1} & a_{x2} & \cdots & a_{xN} & b_{x1} & b_{x2} & \cdots & b_{xN} \\ a_{y1} & a_{y2} & \cdots & a_{yN} & b_{y1} & b_{y2} & \cdots & b_{yN} \\ a_{z1} & a_{z2} & \cdots & a_{zN} & b_{z1} & b_{z2} & \cdots & b_{zN} \end{bmatrix}^T$$

$$z_w = [\Delta\beta_1 \ \ \Delta\beta_2 \ \cdots \ \Delta\beta_N \ \ \Delta\varepsilon_1 \ \ \Delta\varepsilon_2 \ \cdots \ \Delta\varepsilon_N]^T \tag{8}$$

$$e = [\delta\beta_1 \ \ \delta\beta_2 \ \cdots \ \delta\beta_N \ \ \delta\varepsilon_1 \ \ \delta\varepsilon_2 \ \cdots \ \delta\varepsilon_N]^T$$

Where

$$\Delta\beta_i = \beta_{mi} - \beta_{0i}, \quad \Delta\varepsilon_i = \varepsilon_{mi} - \varepsilon_{0i}, \quad \delta\beta_i = \beta_{mi} - \beta_i, \quad \delta\varepsilon_i = \varepsilon_{mi} - \varepsilon_i \tag{9}$$

and β_{mi}, ε_{mi} are, respectively, the bearing angle and the measured angle of elevation of the i^{th} radar. Substituting equations (8) and (9) into equation (5), we have:

$$z_w = H_w \delta x + e \tag{10}$$

Assuming that the measured error e is the zero mean value normal white noise whose covariance matrix being

$$R_w = E[e \ \ e^T] = \mathrm{diag}[\sigma_{\beta_1}{}^2 \ \ \sigma_{\beta_2}{}^2 \ \cdots \ \sigma_{\beta N}^2 \ \ \sigma_{\varepsilon_1}{}^2 \ \ \sigma_{\varepsilon_2}{}^2 \ \cdots \ \sigma_{\varepsilon N}{}^2] \tag{11}$$

and based on estimation theory, the weighted least square estimation of δx being

$$\widehat{\delta x} = (H_w^T R_w H_w)^{-1} H_w^T R_w^{-1} z_w \tag{12}$$

and the estimated target location is

$$z = [\hat{x}_w \ \ \hat{y}_w \ \ \hat{z}_w]^T = x_0 + \widehat{\delta x} \tag{13}$$

2. Covariance of location estimation error

Location estimation error of a target can be expressed as

$$n = x_T - z = \delta x - \widehat{\delta x} = \widetilde{\delta x} \tag{14}$$

hence the covariance of location estimation error of a target is

$$R = E[n \ \ n^T] = E[\widetilde{\delta x} \ \ \widetilde{\delta x}^T] = (H_w^T R_w^{-1} H_w)^{-1} \tag{15}$$

It can be seen that the location accuracy for target emitter depends not only on various radar station's measuring accuracy, but also on the target's location relative to the location of various radar stations as well (Figure 2).

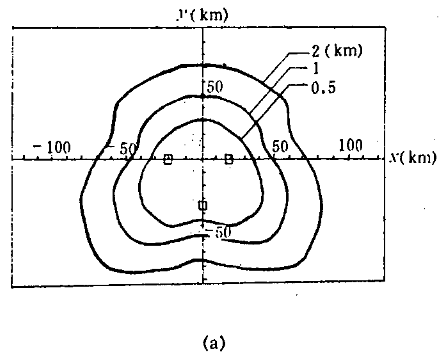


Figure 2. Error Distribution of Weighted Least Square Estimation

□ Denotes radar station.
Standard deviation of location measuring error is 0.01 rad

The lines in the isogram represent the maximum values of standard deviation of location estimation error.

3. Rough estimation of target location

The target's approximate location must be known in advance before the weighted least square estimation can be performed on emitter location. The initial rough estimate of the target location could come from airborne intelligence, or the target location measured by radar prior to jamming, as well as from the calculation using data from the direction angle measurement. Using the technique introduced in Reference 5, the following computation equations can be derived based on the theory of least squares:

$$\begin{cases} x_0=[(MN-U^2)Q+(UV-NT)R+(TU-MV)S]/D \\ y_0=[(UV-NT)Q+(LN-V^2)R+(TV-LU)S)]/D \\ z_0=[(TU-VM)Q+(TV-LU)R+(LM-T^2)S]/D \end{cases} \quad (16)$$

where:

$$D=LMN+2TUV-T^2N-V^2M-U^2L$$

$$\begin{aligned} L&=\sum_{i=1}^{N}(l_i^2+t_i^2), & T&=\sum_{i=1}^{N}(l_im_i+t_iu_i), & Q&=\sum_{i=1}^{N}(r_il_i+s_it_i) \\ M&=\sum_{i=1}^{N}(m_i^2+u_i^2), & U&=\sum_{i=1}^{N}(m_in_i+u_iv_i), & R&=\sum_{i=1}^{N}(r_im_i+s_iu_i) \\ N&=\sum_{i=1}^{N}(n_i^2+v_i^2), & V&=\sum_{i=1}^{N}(l_in_i+t_iv_i), & S&=\sum_{i=1}^{N}(r_in_i+s_iv_i) \end{aligned} \quad (17)$$

and

$$\begin{aligned} &l_i=\cos\beta_i, \quad m_i=-\sin\beta_i, \quad n_i=0, \\ &u_i=-\cos\beta_i\sin\varepsilon_i, \quad v_i=\cos\varepsilon_i, \quad t_i=-\sin\beta_i\sin\varepsilon_i, \\ &r_i=l_ix_i+m_iy_i, \quad s_i=t_ix_i+u_iy_i+v_iz_i, \quad i=1,\ 2\cdots,\ N \end{aligned} \quad (18)$$

II. Tracking and Prediction

In order to realize tracking and predicting a target, further data processing can be performed on weighted least square estimation using Kalman filtering. In doing so, not only can the location accuracy be increased, but the predicted value can be provided as the location rough estimation required in subsequent weighted least square estimation, thus decreasing the error in linearization. Figure 3 is the block diagram of this system

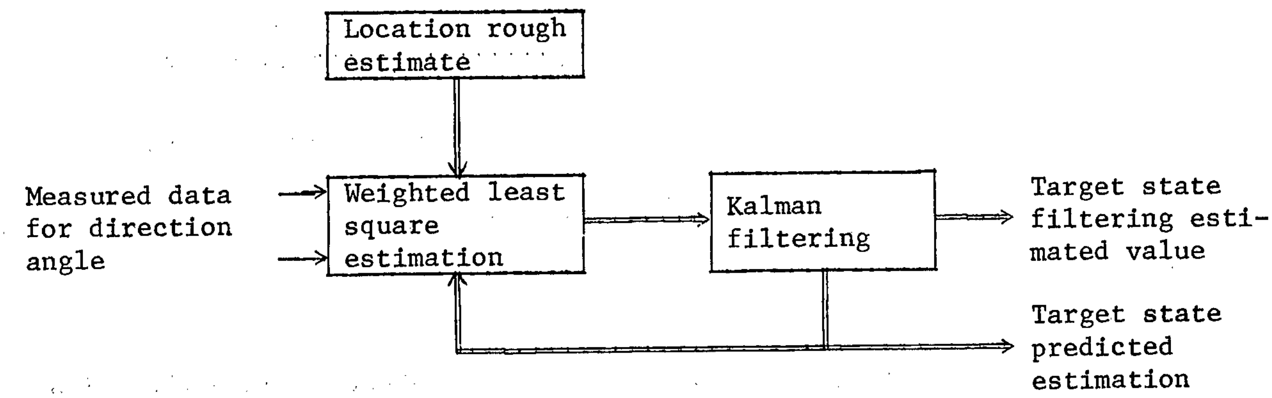


Figure 3. Passive Location System Block Diagram

1. Kalman filtering equation

Assuming the dynamic model for a target is

$$X(k+1)=\Phi X(k)+w(k) \tag{19}$$

where the target state X(k) and state transferred matrix ϕ are, respectively

$$X(k)=[x(k)\ x'(k)\ x''(k)\ y(k)\ y'(k)\ y''(k)\ z(k)\ z'(k)\ z''(k)]^T \tag{20}$$

and

$$\Phi=\left[\begin{array}{ccc:ccc:ccc} 1 & 1 & 1/2 & & & & & & \\ 0 & 1 & 1 & & 0 & & & 0 & \\ 0 & 0 & \rho & & & & & & \\ \hdashline & & & 1 & 1 & 1/2 & & & \\ & 0 & & 0 & 1 & 1 & & 0 & \\ & & & 0 & 0 & \rho & & & \\ \hdashline & & & & & & 1 & 1 & 1/2 \\ & 0 & & & 0 & & 0 & 1 & 1 \\ & & & & & & 0 & 0 & \rho \end{array}\right] \tag{21}$$

where $\rho = e^{-T/Tc}$ is the correlation coefficient of target's accelerated perturbation; T is the data collection cycle, Tc is the correlation time of target's accelerated perturbation.

Perturbation vector w(k) is assumed as

$$w(k)=[0 \quad 0 \quad w_{x''}(k) \quad 0 \quad 0 \quad w_{y''}(k) \quad 0 \quad 0 \quad w_{z''}(k)] \tag{22}$$

This perburbation vector has zero average value, and its covariance matrix

$$Q(k)=E[w(k)w^T(k)]=\mathrm{diag}[0 \ 0 \ \sigma^2_{x''} \ 0 \ 0 \ \sigma^2_{y''} \ 0 \ 0 \ \sigma^2_{z''}] \tag{23}$$

where $\sigma_{x''}$, $\sigma_{y''}$, $\sigma_{z''}$ are, respectively, the standard deviation of the target's accelerated perturbation along the x, y, z coordinates.

Due to the fact that the input data of Kalman filtering is the weighted least square estimate of the target location, the measured model can be obtained as

$$z(k)=HX(k)+n(k) \tag{24}$$

Let n(h) be a mutually exclusive random process, see equation (15) for its covariance, and has a measuring coefficient matrix

$$H=\begin{bmatrix} 1&0&0&0&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0&0 \\ 0&0&0&0&0&0&1&0&0 \end{bmatrix} \tag{25}$$

The following is the equation set of Kalman filtering:

$$\begin{array}{ll}
\text{Predicted estimation eqn} & \hat{X}(k+1/k)=\Phi\hat{X}(k) \\
\text{Predicted estimation} & P(k+1/k)=\Phi P(k)\Phi^T+Q(k) \\
\text{Predicted estimation eqn} & \hat{X}(k+1)=\hat{X}(k+1/k)+K(k+1)[Z(k+1)-H\hat{X}(k+1/k)] \\
\text{Optimal gain matrix} & K(k+1)=P(k+1/k)H^T[HP(k+1/k)H^T+R(k+1)]^{-1} \\
\text{Filtering estimate} & P(k+1)=[I-K(k+1)H]P(k+1/k)[I-K(k+1)H]^T \\
 & \qquad +K(k+1)R(k+1)K^T(k+1)
\end{array} \tag{26}$$

2. Initial and end values in Kalman filtering

The initial estimation $\hat{X}(0)$ of target state can be obtained from the difference of two consecutive weighted least square estimations as follows:

$$\hat{X}(0)=\begin{pmatrix}\hat{x}(0)\\ \hat{x}'(0)\\ \hat{x}''(0)\\ \hat{y}(0)\\ \hat{y}'(0)\\ \hat{y}''(0)\\ \hat{z}(0)\\ \hat{z}'(0)\\ \hat{z}''(0)\end{pmatrix}=\begin{pmatrix}\hat{x}_w(0)\\ [\hat{x}_w(0)-\hat{x}_w(-1)]/T\\ 0\\ \hat{y}_w(0)\\ [\hat{y}_w(0)-\hat{y}_w(-1)]/T\\ 0\\ \hat{z}_w(0)\\ [\hat{z}_w(0)-\hat{z}_w(-1)]/T\\ 0\end{pmatrix} \tag{27}$$

Assuming that the weighted least square estimation is a white random series. According to the computation equation for initial estimation X(0), the initial estimation error covariance matrix P(0) can be expressed in matrix direct accumulation format as[7]:

$$P(0)=C_0\otimes R(0)+C_{-1}\otimes R(-1)+Q(0) \tag{28}$$

where R(-1), R(0) are the error covariance of the first two weighted least square estimations,

$$C_0=\begin{bmatrix}1 & T^{-1} & 0\\ T^{-1} & T^{-2} & 0\\ 0 & 0 & 0\end{bmatrix},\quad C_{-1}=\begin{bmatrix}0 & 0 & 0\\ 0 & T^{-2} & 0\\ 0 & 0 & 0\end{bmatrix} \tag{29}$$

IV. [sic] Simulation Computation and the Results

Simulation computation is performed according to the above mentioned estimation technique and Kalman filtering equation. The conditions in this simulation computation are:

a. Three radar stations are distributed as an equilateral triangle with a distance of 40 km apart.

b. Each radar station simultaneously measures the bearing angle and the angle of elevation of the target relative to that very radar station. It is assumed that each azimuth error is zero mean normal white noise, and whose standard deviation is σ_m for all.

c. The data collection cycle in measuring direction angle, T = 1s.

d. The variance in the target's accelerated perturbation are all assumed equal in the dynamic model used in Kalman filtering, i.e.

$$\sigma^2_{x'} = \sigma^2_{y''} = \sigma^2_{z''} = \sigma^2_a$$

e. The target trajectories fall in four different patterns--flying straight, crabbing, circling, and S-pattern (see Figure 4). Considering the effect of random factors such as atmospheric current on the flying object, we incorporated a random accelerated perturbation in simulating target flight. Based on Reference 2, all of the components assumed herein perturbating in the three direction x, y, z are Markov process, with a correlation time of 1s, and obey the zero mean normal distribution with a standard deviation of 0.1 (m/s^2).

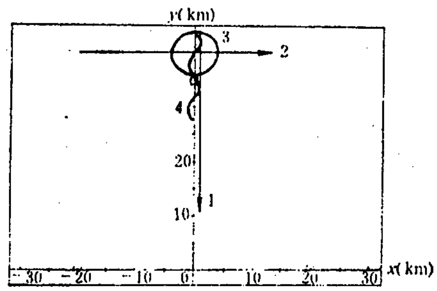


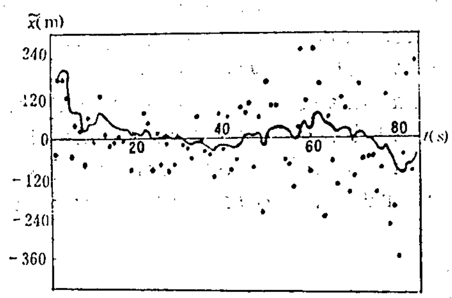
Figure 4. Object Trajectory Plan

1. Flying straight □ Radar station
2. Crabbing
3. Circling
4. S pattern

A portion of the computer simulation results are listed in Table 1 where both the mean and standard deviation are the timing statistical average values of estimation error in the y direction. The simulation results indicated that weighted least square has facilitated a certain level of accuracy in the location process. In situations where the object is taking a nonmaneuvering course (i.e., flying straight, crabbing), Kalman filtering can be further carried out to improve the location accuracy, as illustrated in the results in Figure 5. In situations where the object is taking a maneuvering course (such as circling, S-pattern), the effect of Kalman filtering is not apparent, and therefore procedures have to be taken to modify the model accordingly.

Table 1. Statistical Results of Estimation Error

y Direction	Simulation condition			Weighted least square estimation		Kalman filtering estimate	
N	Trajectory	δ_a (m/s^2)	δ_m (rad)	Mean (m)	Standard deviation (m)	Mean (m)	Standard deviation(m)
1	Flying straight	1	0.01	−6.9390	151.77	−5.4877	48.417
2		10	0.01	−6.9420	151.38	−3.3070	74.384
3	Crabbing	1	0.01	−22.834	165.12	−105.311	62.863
4		10	0.01	−20.739	162.52	−92.632	76.239
5	Circling	1	0.01	−40.435	233.09	267.57	677.45
6		10	0.01	−56.392	202.02	−114.47	121.69
7	S pattern	1	0.01	−30.837	140.78	−58.160	84.740
8		10	0.001	−3.0930	13.898	−4.038	8.5215



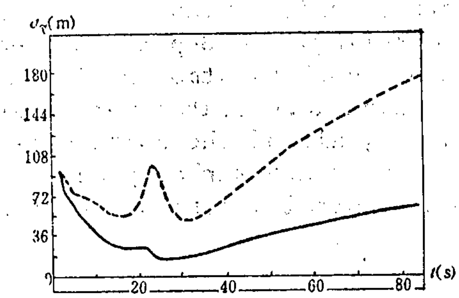


Figure 5. Estimation Error and Its Standard Deviation Curve (n=1)

V. Conclusion

Passive location is a feasible procedure capable of combatting a moving target carrying an active emitter. In order to locate such target more efficiently, measurement data on direction angle should be obtained using as many methods as possible, such as laser, ultra violet light, television tracking equipment, and so on. Target tracking and prediction can be realized when the target location estimated value obtained in weighted least square estimation is fed into Kalman filtering.

In the case of multiple emitters, the multiple emitters can be identified by employing the method of correlation, using the predicted data provided in Kalman filtering and data in estimation covariance.

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APPLIED SCIENCES

OPTIMAL SELECTION OF PRODUCTION PLAN, SOFTWARE DESIGN

Beijing ZIDONGHUA XUEBAO [ACTA AUTOMATICA SINICA] in Chinese Vol 11 No 1, Jan 85 pp 87-93

[Article by Fan Fu [2868 3940] of the Institute of Computer Application, the Ministry of Nuclear Industry; Manuscript received on 21 March 1983]

[Text] Abstract: An actual example of applying a microcomputer to production management is introduced in this paper. The method to solve the problem and the software are discussed. The economic benefit of this software is expanding year after year.

How to use a computer to optimize the management of a production process is an important research subject in production management. An actual example is introduced in this paper. For a specific production process, the focal point of the problem is that not only do we need an appropriate mathematical model to reflect the production process, but also more importantly, we have to design high performance applications software based on this model. Then, the optimal production plan with the lowest cost and highest productivity can be chosen by the computer.

I. Production Process and Its Mathematical Model

The production process is shown in Figure 1. The variables of this industrial process are: 1) locations of loading and unloading; 2) number of reaction towers and number of plates in each tower; and 3) rate of loading and unloading per unit time. The entire system can be optimized by choosing these factors.

The entire process can be divided into three stages based on the operating time: 1) Start-up stage. During which the material has not yet reached the specified concentration at the outlet so that there is only power consumption but no product; 2) Steady-state operation stage. The longest lasting stage in which power and materials are consumed and product is produced; and 3) Shut-down stage. Power is consumed, raw materials are not added and product is still being produced. The mathematical models for these three stages are as follows:

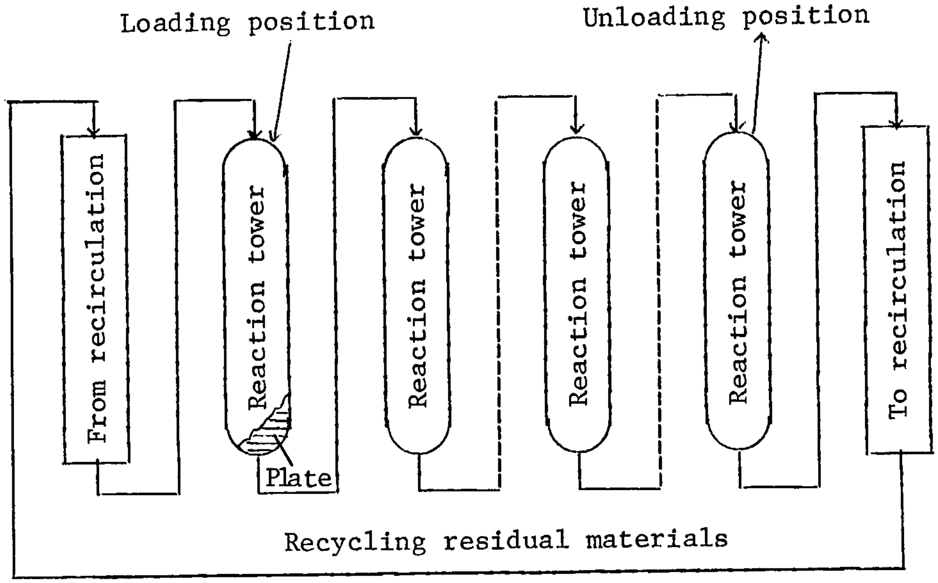

Figure 1. A Chemical Engineering Flow Diagram

1. Nonsteady-state Equation in the Start-up Stage

$$
\begin{aligned}
&H(n)\frac{\partial C}{\partial t} = \frac{\partial}{\partial n}\left\{J_a(n)\left[\frac{\partial C}{\partial n} - \frac{\varepsilon C(1-C)}{1+\varepsilon C}\right]\right\} \\
&\qquad + [F\theta(n_F - n) - \tau\theta(n_k - n)]\frac{\partial C}{\partial n} \\
&\qquad + F(C_F - C)\delta(n - n_F), \\
&t = 0 \text{ 时}, \ C(n, 0) = C_0, \\
&n = 0 \qquad (H(n) + H_W)\frac{\partial C}{\partial t} = J_a(n)\left[\frac{\partial C}{\partial n} - \frac{\varepsilon C(1-C)}{1+\varepsilon C}\right] + (F - \tau)\frac{\partial C}{\partial n}, \\
&n = S \qquad -H_K\frac{\partial C}{\partial t} = J_a(n)\left[\frac{\partial C}{\partial n} - \frac{\varepsilon C(1-C)}{1+\varepsilon C}\right].
\end{aligned}
\tag{1}
$$

where

$$J_a(n) = J_0\left(1 - \frac{1}{2}bn\right)^2,$$

$$\theta(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0, \end{cases} \qquad \varepsilon = \begin{cases} \varepsilon_1 & 0 \leq n \leq n_F \\ \varepsilon_2 & n_F < n \leq S; \end{cases}$$

$$H(n) = (Q_P Q + V)N_P(n) + Q_a Q N_a(n).$$

where $N_a(n) = N_0\left(1 - \frac{1}{2}bn\right)^2$, $N_P(n)$ is a monotonically decreasing positive step function.

$$Q = \begin{cases} Q_1 & 0 \leq n \leq n_0 \ (n_0 \text{ is the end of the second tower}) \\ Q_2 & n_0 < n \leq S; \end{cases}$$

$$V = \begin{cases} V_0 & \text{at discontinuous points of Np(n) (i.e., the boundary of two towers)} \\ 0 & \text{other n} \end{cases}$$

In the equations above, Q_1, Q_2, V_0, Q_a, Q_P, N_0, J_0, b, ε_1, ε_2, n_0, n_F, n_K, S and F, τ, C_F, C_0, H_W, H_K are known constants. The equation is solved on $n \in [0,S]$. The nodal points are arranged as follows:

$$0 = n_W < n_F < n_K \leqslant n_S = S$$

The characteristic of the start-up period is $F = 0$, $\tau = 0$. In solving the equation, the time $t = T_1$ at which the condition $C(n_K, t) \geqslant C_k$ (constant) is satisfied is the first equilibrium time. At this moment, the materials are enriched. The residual material (i.e. the value of $C(0,t)$), however, has not yet equilibrated. Then, materials are fed into ($F \neq 0$) and taken out of ($\tau \neq 0$) the system. By the time T_2, the residual material is also equilibrated. This is the second equilibrium time. At this moment, the solution of the start-up period is over. The quantities to be determined in this stage are T_1, T_2, $C(n, t), \int_0^t F\,dt, \int_0^t \tau\,dt$, etc. (Footnote) (The definitions of the parameters are as follows: n is the number of the tower plate coordinate, n_W is the initial tower plate coordinate, n_F is the feeding point coordinate, n_K is the fetching point coordinate, n_S is the last tower plate coordinate, $C(n,t)$ is a concentration function, C_0 is the initial concentration constant of the system, C_F is the concentration constant of the feed, C_K is the concentration constant of the output, F is the rate of feeding, τ is the rate of production, ε_1 is separation coefficient 1, ε_2 is separation coefficient 2, b is the percent of material decomposition, $H(n)$ is the amount of materials remaining in the n^{th} tower, H_W is the amount of materials remaining in the front recirculation area, H_K is the amount of materials remaining in the back recirculation area, $J_a(n)$ is the flow rate of the material, $Np(n)$ is the tower-related equivalent concentration, and $N_a(n)$ is the tower plate related equivalent concentration.)

2. Equation of Steady-state Operation After System Is in Equilibrium

$$\frac{dC}{dn} = \frac{\varepsilon C(1-C)}{1+\varepsilon C} + \frac{F(C_F - C)\theta(n_F - n) - \tau(C_K - C)\theta(n_K - n)}{J_a(n)},$$

when $n = n_F$, $C(n_F) = C_F$. When $n = n_k$, $C(n_k) = C_k$.

The conservation of materials is $F = \tau + W$.

The conservation of concentrations is $FC_F = \tau C_K + WC(0)$. (2)

where ε, $\theta(x)$, $J_a(n)$, C_F, and C_K are defined as before. W is the residual rate and $C(0)$ is the residual concentration. The quantities to be determined are F, τ, and W and the steady state curve $C(n)$.

3. Nonsteady-state Equation in the Shut-down Period

The nonsteady-state equation in this case is, in general, similar to that in the shut-down stage. There are, however, the following differences:

1) The characteristic of the operation of a shut-down system is $F = 0$ and $\tau \neq 0$. In addition, there is the following initial condition $C(n,0) = C(n)$ (steady state solution).

2) The value of τ is altered in the solution-finding process to satisfy $C(n_K,t) = C_K$. In order to do so, it takes more iteration time. The following equation may be used instead:

$$\tau - \tau \pm \Delta\tau, \quad |C(n_K, t) - C_K| < \eta.$$

Here, $\Delta\tau$ is the increment of τ and η is the control constant of C_K.

3) When the residual concentration is too low, i.e., $C(0,T) < C_{W_0}$ (control constant), the solution-finding process ends.

The quantities to be determined are identical to those in the shut-down period, however, the physical meanings at time T are different.

II. Essence of the Problem

The selection of the optimum production scheme is essentially the minimization of the target function m, the unit cost of the product. The constraints are the equations described in the above mathematical model. Therefore, it is a differential constraint problem with regular and partial differential equations. The equation to calculate m is

$$m - \sum_{i=1}^{5} a_i/M.$$

where a_i are the following expenses: consumption of raw materials, wear and tear of equipment such as pumps, power consumption (water, electricity, and steam), shop expenses (wages and capital), and management costs (transportation, maintenance and product analysis). The first three items may become a part of cost; related to parameters such as F and J_0. The product value M is related to τ. These can be manually selected. In this single goal nonlinear planning problem, there are more than 40 varying parameters. It will take too much time to use a mathematical planning method to solve it. Hence, the following method is used. Some parameters are rationally adjusted within the conditions and ranges permitted in production. Then the mathematical model is solved to determine m. An optimum production scheme is chosen with a small m.

III. Mathematical Treatment

1. Solving the Difference Equation of Equation (1)

Equation 1 is a nonlinear parabolic equation. Its boundary conditions are very complex. The Crank-Nicolson estimation-correction algorithm is used. Let us assume that the spatial step in the n direction is h and the time step in the t direction is Δt. Then

$$C(kh, j\Delta t) - C_{k,j}.$$

The difference equation to solve is[3]

$$n = 0: \quad (A+B)C_{0,j+l} - BC_{1,j+l} = \begin{Bmatrix} AC_{0,j} \\ (A-B)C_{0,j} + BC_{1,j} \end{Bmatrix}$$

$$- 2lh\left[J_a^{\frac{1}{2}}\left(\frac{\varepsilon C(1-C)}{1+\varepsilon C}\right)_{\frac{1}{2},j+l-\frac{1}{2}} - A'\left(\frac{\varepsilon C(1-C)}{1+\varepsilon C}\right)_{0,j+l-\frac{1}{2}}\right],$$

$$n = kh(k = 1, 2, \cdots\cdots S-1): \ -(J_a^{k-\frac{1}{2}} - D)C_{k-1,j+l}$$

$$+ (J_a^{k+\frac{1}{2}} + J_a^{k-\frac{1}{2}} + E + F^0)C_{k,j+l} - (J_a^{k+\frac{1}{2}} + D)C_{k+1,j+l}$$

$$= \begin{Bmatrix} F^0 C_{k,j} \\ (J_a^{k-\frac{1}{2}} - D)C_{k-1,j} - (J_a^{k+\frac{1}{2}} + J_a^{k-\frac{1}{2}} + E - F^0)C_{k,j} + (J_a^{k+\frac{1}{2}} + D)C_{k+1,j} \end{Bmatrix}$$

$$- 2lh\left[J_a^{k+\frac{1}{2}}\left(\frac{\varepsilon C(1-C)}{1+\varepsilon C}\right)_{k+\frac{1}{2},j+l-\frac{1}{2}} - J_a^{k-\frac{1}{2}}\left(\frac{\varepsilon C(1-C)}{1+\varepsilon C}\right)_{k-\frac{1}{2},j+l-\frac{1}{2}} - E\right],$$

$$n = S: \ -C_{S-1,j+l} + (G+1)C_{S,j+l} = \begin{Bmatrix} GC_{S,j} \\ C_{S-1,j} + (G-1)C_{S,j} \end{Bmatrix}$$

$$- 2lh\left(\frac{\varepsilon C(1-C)}{1+\varepsilon C}\right)_{S-\frac{1}{2},j+l-\frac{1}{2}}. \qquad (3)$$

The upper formula in the bracket in the above equation is used for estimation and the lower one is used for correction. In addition, it is specified that:

$$l = \begin{cases} 1/2 & \text{for estimation} \\ 1 & \text{for correction,} \end{cases} \quad r = \Delta t/h^2, \quad J_a^i = J_a(n_i) = J_a(ih),$$

$$H^i = H(n_i), \quad J_a^{k+\frac{1}{2}} = (J_a^k + J_a^{k+1})/2.$$

The abbreviated quantities are

$$A^0 = \frac{J_a^0(H^0 + H_W)}{J_a^0 + F - \tau} \text{ used in the equilibrium equation later)}$$

$$A' = \frac{J_a^0(F-\tau)}{J_a^0 + F - \tau}, \ A = \frac{H^0 + 2A^0/h}{r}, \ B = J_a^{\frac{1}{2}} + \frac{(F-\tau)}{2}h,$$

$$D = \frac{h}{2}[F\theta(n_F - kh) - \tau\theta(n_k - kh)], \quad E = Fh\delta(kh - n_F),$$

$$F^0 = \frac{2H^k}{r}, \ G = \left(H^S + \frac{2H_K}{h}\right)\Big/ rJ_a^{S-\frac{1}{2}}.$$

Equation (3) is solved by the successive approximation method. The known value of the initial layer is used to determine the unknown in the next layer and so on. Because equation (1) contains a nonlinear term, it is necessary to use the estimate formula to find the initial iteration value and then employ the correction formula to perform multiple iterations until the accuracy requirement is met. Equation (3) can be rewritten as:

$$A_k\varphi_{k-1} + B_k\varphi_k + C_k\varphi_{k+1} = F_k \quad (k = 0, 1, 2, \cdots S, \text{where } A_0 = C_S = 0),$$

The successive approximation equations are

$$D_k = \frac{C_k}{B_k - A_k D_{k-1}}, \quad D_0 = \frac{C_0}{B_0},$$

$$E_k = \frac{F_k - A_k E_{k-1}}{B_k - A_k D_{k-1}}, \quad E_0 = \frac{F_0}{B_0},$$

$$\varphi_k = E_k - D_k \varphi_{k+1}, \quad \varphi_S = E_S.$$

Because the six point standard Crank-Nicolson difference scheme is invariantly stable, the difference schemes for boundary and internal points approach second order accuracy, i.e. the truncation error is $O(h^2 + \Delta^2 t)$. Therefore, the coefficient matrix satisfies the diagonal priority condition and the successive approximation process is stable. Equation (1) contains nonlinear terms, therefore, the estimation-correction technique is used. Due to the fact that equation (1) has a steep apex, we also perform iterations of the correction formula. Thus, the solution is consistently convergent.[2] In addition, in order to keep equation (3) conservative at the apex of H(n), as well as at discontinuity points F, τ, ε, these points are chosen to be grid points. In addition, the average value is chosen at the discontinuity to significantly weaken the fluctuation of the solution. Through calculation, this treatment has been proven to be correct.[3] The error E_j at the j^{th} level is estimated to be:

$$E_j^{(n)} = \max_i \left| \frac{C_{i,j}^{(n)} - C_{i,j}^{(n-1)}}{C_{ij}^{(n)}} \right|, \quad |E_j^{(n)}| < \delta.$$

Here, n is the number of iterations and δ is the given accuracy.

The following equilibrium equation is used to check the solution of equation (3); i.e. to integrate equation (1) from 0 to S and from t to t + Δt, and to plug in the boundary conditions on both sides:

$$\begin{aligned} S(t+\Delta t) - S(t) = & -H_K(C_{S,j+1} - C_{S,j}) - A^0(C_{0,j+1} - C_{0,j}) \\ & + \Delta t\left\{A'\left(\frac{\varepsilon_1 C(1-C)}{1+\varepsilon_1 C}\right)_{0,j+\frac{1}{2}} + F(C_F - C_{0,j+\frac{1}{2}}) - \tau(C_{n_K,j+\frac{1}{2}} - C_{0,j+\frac{1}{2}})\right. \\ & \left. + J_a^{n_F}\left[\left(\frac{\varepsilon_2 C(1-C)}{1+\varepsilon_2 C}\right)_{n_F,j+\frac{1}{2}} - \left(\frac{\varepsilon_1 C(1-C)}{1+\varepsilon_1 C}\right)_{n_F,j+\frac{1}{2}}\right]\right\}. \end{aligned}$$

where $S(t) = \int_0^S H(n)C(n,t)dn$. A trapezoidal approximation is used to satisfy the verification requirement. Its truncation error is also $O(h^2)$.

2. Solving the Steady-state Equation (2)

Equation (2) is a first order normal differential equation. We used the Runge-Kutta method to solve it. We can choose five different orders of Runge-Kutta methods in the software. For this equation, as demonstrated in practice, the second order middle point Runge-Kutta method was found to be most efficient and accurate. Its algorithm is listed in the following.[1] Let us assume that the different equation is

$$\begin{cases} y' = f(x, y), \\ y(x_0) = y_0, \end{cases}$$

Let h be the step length, $x_n = x_{n-1} + h$, $f_n = f(x_n, y_n)$, then the iteration formula is

$$y_{n+1} = y_n + hf\left(x_n + \frac{1}{2}h, y_n + \frac{h}{2} f_n\right).$$

Because the right hand side of equation (2) contains unknown F and τ which also satisfy two other equations of conservation. Hence, the following steps should be used to solve it.

1) First, it is solved in $[n_F, n_K]$. In this case, F = 0. Let us set two different initial values for τ. We moved from n_k toward the left to find two different values for $C(n_F)$. Then, $C(n_F)$ is considered as a function of τ. A new value of τ is obtained by linear interpolation. In addition, equation (2) is also solved to obtain a new $C(n_F)$ value. A better point near C_F is chosen from two previous sets of $(\tau, C(n_F))$ to be linearly interpolated with the new point. The iteration is repeated until the τ value obtained satisfies the accuracy requirement.

2) F is first determined in $[0, n_F]$. Two different initial F values are set to solve the equation from the left of n_F to obtain two different values of C(0). Based on the conservation equation, the left side points should satisfy

$$D = C(0) - (FC_F - \tau C_K)/(F - \tau) = 0.$$

D is considered as a function of F. A new value of τ is determined by linear interpolation with two known points (F, D). The iteration is repeated until the required accuracy is reached.

IV. Program Design

The name of the software is FANNS812.COM, which is written in FORTRAN to be used on the CROMEMCO-B microcomputer. In addition, object files directly accessible by the user are also generated. The overview of the software is:

1) Man-machine dialogue is used to interface the user for ease of operation.

2) After all parameters are displayed on the CRT (or printer), the user may modify them on the keyboard and redisplay them. The flexibility and reliability of the data is thus ensured. The user may also choose the printing format of the calculated results. This output flexibility also guarantees that various user needs are met. It also saves computer time.

3) The program also displays various operating messages to help the operator to understand the progress. During the process, we still can modify the parameters and continue the original calculation. Intermediate results may be stored on disks so that the calculation may continue in case of any malfunction, to save time.

4) The program can be run based on our choice; i.e., the start-up, steady-state, and shut-down stages can be calculated individually (by modifying the working parameters) or as a whole.

5) The functionality is expanded. For instance, in steady-state and nonsteady-state calculation, approximations are used (to simplify the nonlinear term as $\varepsilon C(1 - C)$. When shutting down, we can iterate with respect to τ. There are multiple choices for the time grid (three kinds: equal steps, discrete, and software adjusting). In the nonsteady-state calculation process, the time step may be changed arbitrarily.

The primary block diagram of the software is shown in Figure 2.

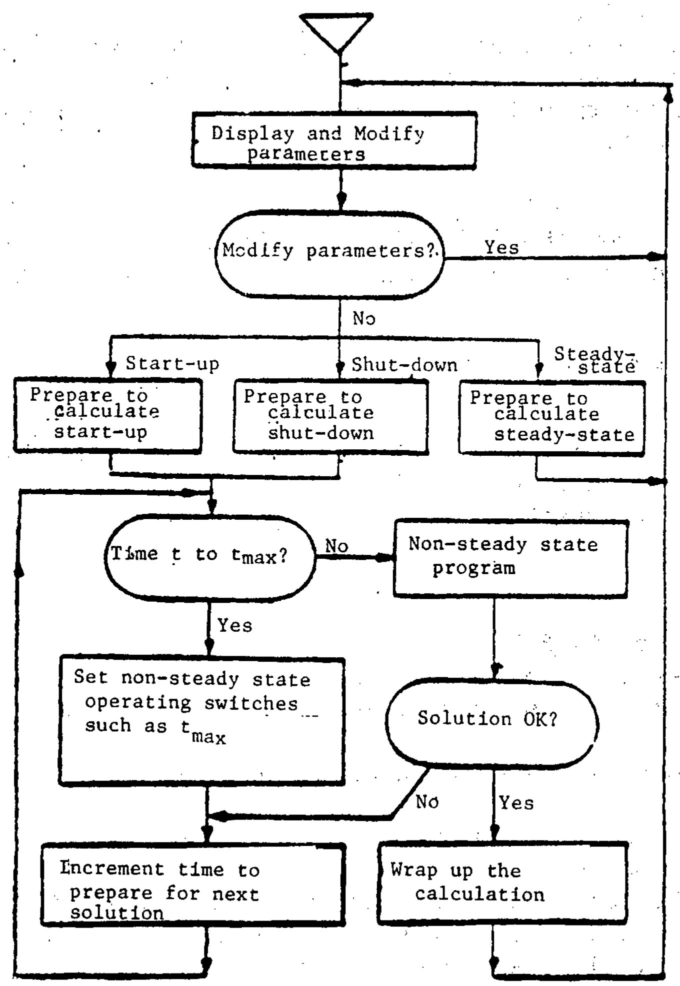

Figure 2. Primary Block Diagram of the Software

V. Effectiveness of the Application

Good formulas were chosen in the software design, therefore, the number of iterations required to obtain the solution is very small. On a microcomputer, it takes more than an hour to calculate a start-up or a shut-down process, and

approximately 2 minutes for a steady-state calculation. The calculated results can completely agree with the physical process in production and meet the accuracy requirement. Because the software correctly simulates the production process, the economic benefit is most outstanding:

1) Through a simulation of the start-up stage, the idling time is shortened by 1 day, resulting in an additional profit of over 80,000 yuan per run.

2) The selection of the steady-state operating plan can result in the optimal technical parameters. The plant reformed its technology based on the steady-state results, leading to 85.71 percent higher profit in 1983 as compared to 1982.

3) The optimization of the shut-down process allows full recovery of products in residual materials. A new shut-down plan was adopted in late 1981, resulting in an additional profit of 100,000 yuan

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APPLIED SCIENCES

COMPUTER-AIDED DESIGN OF OPTIMUM LINEAR CONTROL SYSTEMS

Beijing ZIDONGHUA XUEBAO [ACTA AUTOMATICA SINICA] in Chinese Vol 11 No 1, Jan 85 pp 38-43

[Article by Wang Qinyou [3769 2953 0645] of Shaanxi Institute of Mechanical and Electrical Engineering; Manuscript received on 22 October 1981]

[Text] Abstract: In this paper a computer-aided design method for optimum linear time-invariant systems satisfying both quadratic performance index and time-domain performance index is described. The function of the CAD package and the algorithm of spectral factoring to solve for the optimum system are presented. An actual example of the design has shown that the design method performs well.

Various methods can be used to design linear time-invariant systems. In this paper a double index design method is used. That is to require that the system to be designed must simultaneously satisfy a quadratic performance index and a time-domain performance index. The advantage of this design method is that it is capable of linking the optimum system designed to time-domain performance in order to make the system more practical.

I. System Design Indices

1. Quadratic Performance Index

Let us assume that the reference input of the system is r(t), the system error is e(t), and the amount of control imposed on the control object G(s) is u(t). At a specific value q, the system which is capable of making the generalized index function[1]

$$J = \int_0^\infty [qe^2(t) + u^2(t)]dt \tag{1-1}$$

to reach its minimum is called the optimum system I.

According to quadratic performance index J, the transfer function of the optimum system I can be determined based on the extremum theorem[2]:

$$\Phi_I(s) = \frac{q}{r(s)} \left\{\frac{G^N(-s)r(s)}{D(-s)}\right\}^+ \frac{G^N(s)}{D(s)}. \tag{1-2}$$

where r(s) is the image function of the input reference r(t). D(s) is one of the solutions of the following equation:

$$D(s)D(-s) = qG^N(s)G^N(-s) + G^D(s)G^D(-s) \tag{1-3}$$

where $G^N(s)$ and $G^D(s)$ are the polynomial numerator and denominator of G(s), respectively.

$$\{G^N(-s)r(s)/D(-s)\}^+$$

represents the sum of the rational fraction in the $G^N(-s)r(s)/D(-s)$ expansion when the extremum is located on the left side of s.

2. Time-Domain Performance Index

An optimum system I which satisfies a given time-domain performance index is called an optimum system II; or the optimum system for short.

Let us assume that the p time-domain performance indices are J_i, then the optimum system II can be expressed as:

$$\Phi_{II}(s) = \Phi_I(s)\{\varphi_i \leqslant J_i, i = 1,2,\cdots,p\}. \tag{1-4}$$

where φ_i represents the time-domain parameter corresponding to the optimum system I.

The time-domain performance indices of a system may be selected based on the actual need. In this paper several common indices such as Mp (over-shoot), t_r (rise time), t_s (transition time or adjustment time), N_s (number of instantaneous oscillations), e_r (allowed system error) and u_m (peak amount of control) are used.

II. System Design Method

1. The Design Method for the Optimum System

According to the characteristics of the optimum system I, its transfer function can be separated into two parts, i.e.

$$\Phi_I(s) = F_0(s)\Phi_0(s). \tag{2-1}$$

where

$$F_0(s) = \frac{Kq}{r(s)}\left\{\frac{G^N(-s)r(s)}{D(-s)}\right\}^+, \tag{2-2}$$

$$\Phi_0(s) = \frac{G^N(s)}{KD(s)} \tag{2-3}$$

are the secondary and primary parts of $\Phi_I(s)$, respectively. K is a constant yet to be determined in choosing the form of the primary and secondary parts.

In the design process the primary and secondary parts are separately calculated to reduce the work load. The design process of the optimum system I is shown in Figure 1.

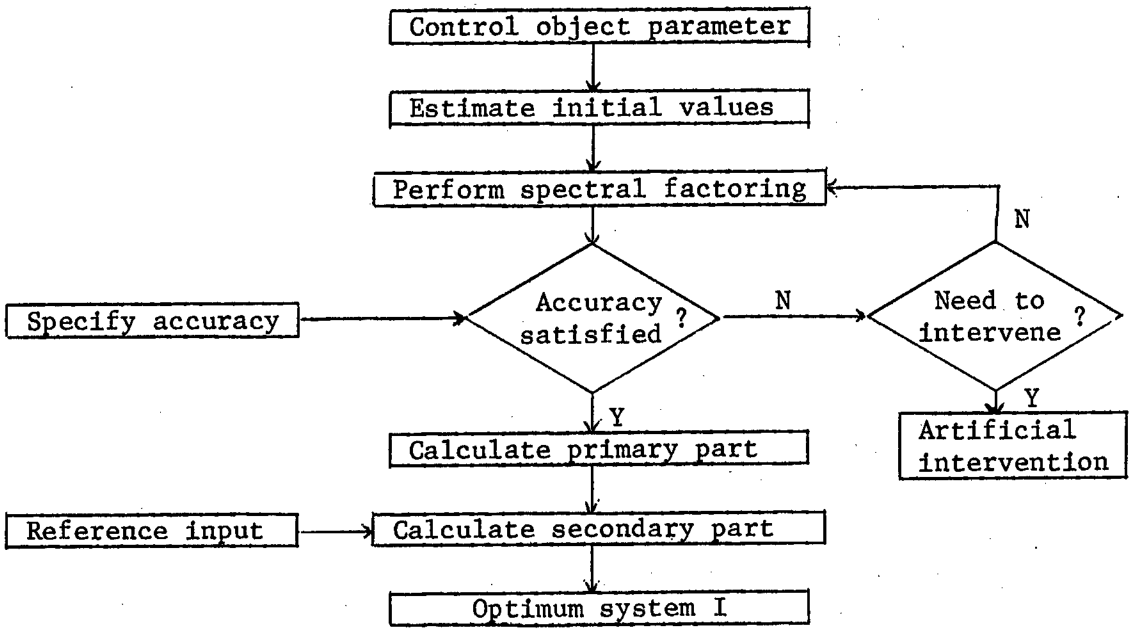

Figure 1. Design Process of Optimum System I

As for the reference input, we may choose from commonly used step, ramp, parabola or sinusoidal functions.

2. Spectral Factoring

The polynomial D(s) must be used to calculate the optimum System I. To solve D(s) based on equation (1-3) is spectral factoring. In the following an improved Newtonian method[3] will be introduced to perform spectral factoring.

Let us assume that the coefficient of the s^i term of D(s) is x_i. Let

$$\begin{cases} f_i(\boldsymbol{x}) = \sum_{j=0}^{2i} (-1)^j x_{2i-j} x_j, \\ c_i = \sum_{j=0}^{2i} (-1)^j (q g^N_{2i-j} g^N_j + g^D_{2i-j} g^D_j), \end{cases} \quad (i = 0,1,2,\cdots,n) \tag{2-4}$$

Then the nonlinear equation to solve the vector x is

$$\boldsymbol{f}(\boldsymbol{x}) = \boldsymbol{c}, \tag{2-5}$$

It may also be rewritten as

$$\boldsymbol{y}(\boldsymbol{x}) = 0. \tag{2-6}$$

where

$$y(x) = f(x) - c. \tag{2-7}$$

where g_i^N and g_i^D are the coefficients of the s^i terms of $G^N(s)$ and $G^D(s)$.

The Jacobian matrix of y(x) is

$$D[y(x)] = 2 \cdot \begin{bmatrix} x_0 & 0 & 0 & \cdots & 0 \\ x_2 & -x_1 & x_0 & \cdots & 0 \\ x_4 & -x_3 & x_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & & \vdots \\ 0 & 0 & 0 & \cdots & (-1)^n x_n \end{bmatrix}. \tag{2-8}$$

Based on the fact that many elements at the upper right corner and the lower left corner of D[y(x)] are zero, a small amount of calculation may be used to convert it into a lower triangular matrix U(x). In order to prevent U(x) from lowering its order, its main diagonal elements may be treated as follows:

$$u_{ii}(x) = \begin{cases} u_{ii}(x) & (|u_{ii}(x)| \geqslant \varepsilon) \\ \varepsilon & (|u_{ii}(x)| < \varepsilon), \end{cases} \quad (i = 0,1,2,\cdots,n) \tag{2-9}$$

As we convert D[y(x)] into U(x) by linear transformation, y(x) is also linearly transformed into v(x). Let

$$z(x) = U^{-1}(x)v(x), \tag{2-10}$$

Hence, we get the iteration equation to solve x

$$\begin{cases} x_{k+1} = x_k - \omega_k z_k, \\ \omega_k = \begin{cases} \omega\{\min\limits_{\omega \in [\omega_0, \omega_1]} \|y(x_k - \omega z_k)\|\}, & (\|y_k\| \geqslant M), \\ 1, & (\|y_k\| < M). \end{cases} \end{cases} \tag{2-11}$$

where ε and M are the smaller and larger given positive numbers, respectively. ω_0 and ω_1 indicate the range of ω.

The iteration equation (2-11) has no rigorous requirement on the initial value x_0. Hence, the initial value can be roughly estimated by the computer.

The advantage of the spectral factoring method is its fast rate of convergence and high accuracy. Moreover, the user is not required to provide the initial value for the iteration.

3. Design Method for Optimum System II

The design of an optimum system II is carried out by adjusting the q value to allow an optimum system I to satisfy the time-domain index. The design process is shown in Figure 2.

The main workload in the design of an optimum system II is in the digital simulation of the system time-domain. In order to improve the design efficiency, a fast and accurate simulation method--the equivalent transfer method is used in this work for the digital simulation of the system.

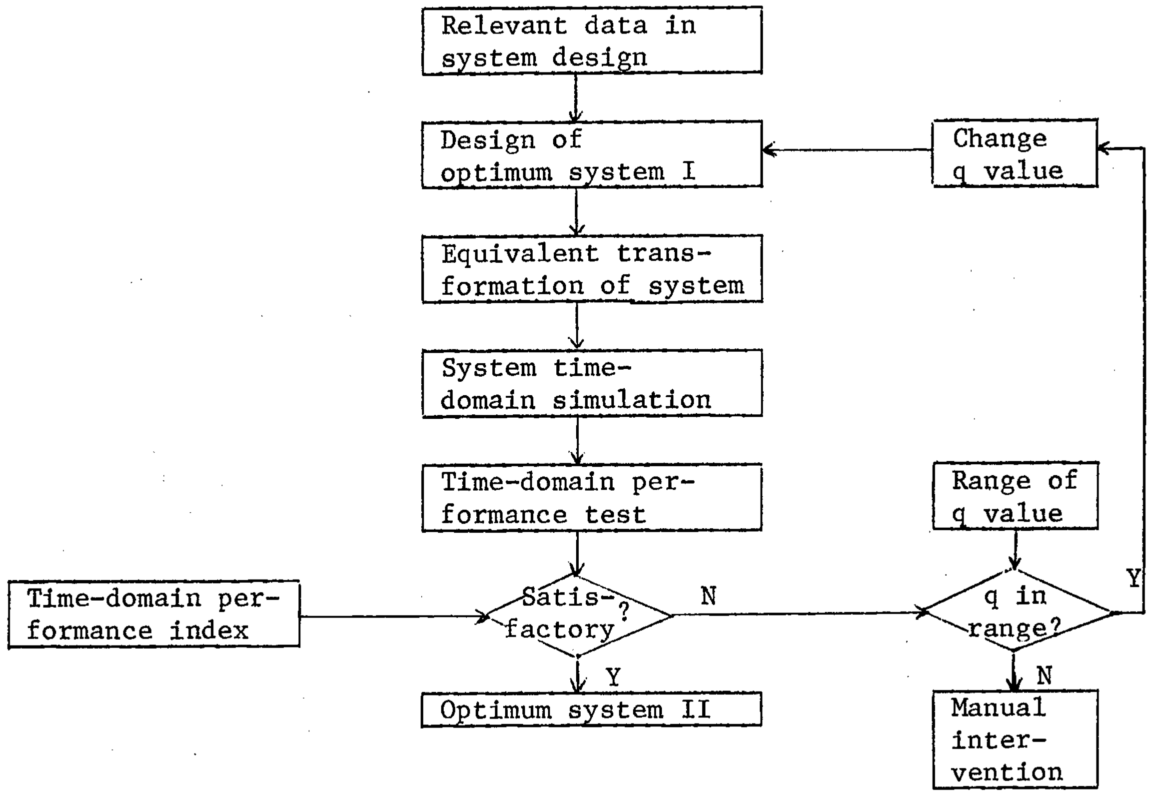

Figure 2. Design Process of Optimum System II

4. Design Method for System Compensators

After the optimum system is calculated, we should also design a corresponding compensator (or calibrator) in order to link it with G(s) to become the optimum control system. Various compensating methods such as compound calibration, serial calibration, status feedback calibration, and partial status feedback are used. The purpose of having various compensating methods is to make it convenient for the user to select. The algorithm of a feedback compensator can be found in Reference 1.

III. Program Structure and Function

The primary function of the CAD program in this paper is limited in two areas: one is to use the computer to perform data processing in the system design process and the other is to establish the man-machine dialogue (primarily for manual intervention). Figure 3 is a schematic diagram of the program structure.

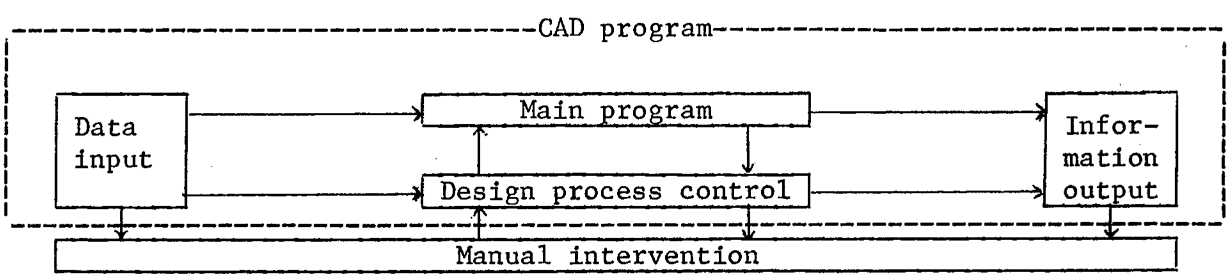

Figure 3. Schematic Diagram of the Program Structure

The basic functions of various parts of the program are as follows:

1) Data Input. Data input includes the input of controlled device parameters, design indices, and request and control commands. If the designer does not intend to intervene in the design process, the CAD program can automatically complete the entire design work.

2) Main Program. The main program is the principal part of the CAD program which consists of over a dozen subroutines performing various functions. The basic function is to perform data processing and calculation to complete the design.

3) Design Process Control. The function of design process control is to perform the management of the design process according to the control commands and to establish a channel for manual intervention.

4) Information Output. Messages are sent when abnormalities exist in the design process to facilitate manual intervention. Upon completing the design, various results such as data and tables are sent to the output.

5) Manual Intervention. When the designer decides to intervene, manual intervention is possible. There are two kinds of manual intervention: intervention at fixed points and intervention at any point.

The special features of the above CAD program include its multifunction capability, high efficiency and convenience. This program is capable of finishing the design of optimum linear steady systems below the 20th order at a reasonably fast speed.

IV. Example of System Design

An example of the design of a control system is introduced in the following. Let us assume that the object to control is

$$G(s)=\frac{1600.074}{(0.08s+1)(0.6s+1)s}.$$

and the design requirements are $q\leqslant 10$, $e_r=2\%$, $M_p\leqslant 15\%$, $t_s\leqslant 0.3(\text{sec.})$. The reference input is a step function. Based on the structure of the object to be under control, we will design the status feedback compensator, the transfer function of the output system and its response curve.

The results are as follows. The transfer function of the optimum system is

$$\Phi(s)=\frac{3577.7655}{0.048s^3+4.1s^2+171.2854s+3577.7655}.$$

The time-domain performance indices of the optium system are $e_r=2\%$, $M_p=7.85\%$, $t_r=0.08(\text{sec.})$, $t_s=0.165(\text{sec.})$, $N_s=0.5$ (times), $u_m=0.91$. The method of compensation and the compensator of the optimum system are shown in Figure 4. The response curve of the optimum system is shown in Figure 5.

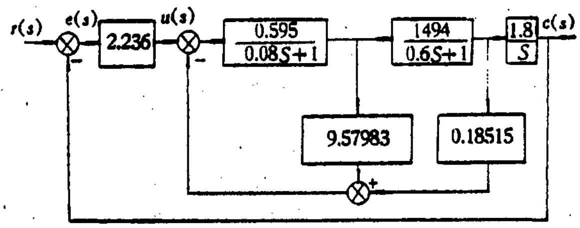

Figure 4. Compensation Method and Compensator for the Optimum System

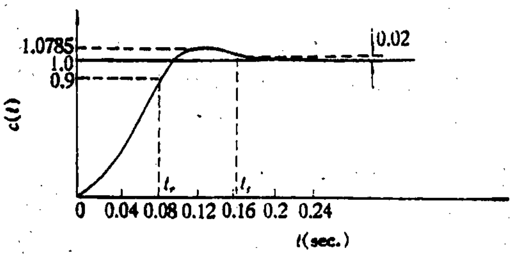

Figure 5. Time-Domain Response Curve of the Optimum System

The above design results show that the system designed by this CAD package has good response characteristics. The outstanding features include its short transition process and small over-shoot.

V. Conclusions

There are various methods to design a single variable linear steady system which satisfies quadratic performance indices. In this paper a spectral factoring method was used. The special feature is that this method can be used to directly determine the transfer function of the optimum system. The algorithm is improved in this work to solve the spectral factoring problem.

When a control system is used in practice, the user is often concerned about the time-domain performance indices of the system. In this paper digital simulation of the time-domain of the system was used to obtain more accurate time-domain performance parameters. These parameters are then used to perform design by constraint. Thus, the optimum design of the system is combined with its time-domain performance index to make the system more practical.

The CAD program introduced in this paper was designed based on the need. Its major features are simplicity, convenience, practicality, and suitability for mini- and microcomputers.

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PHYSICAL SCIENCES

GEOMETRIC NONLINEAR ANALYSIS OF SHELLS

Beijing SHUZHI JISUAN YU JISUANJI YINGYONG [JOURNAL OF NUMERICAL METHODS AND COMPUTER APPLICATIONS] in Chinese Vol 6 No 3, Sep 85 pp 176-187

[Article by Zhang Di [1728 6611], Zhejiang University, and Cai Zhongxiong [5591 0022 3574], Computing Center, Academia Sinica, paper received 18 January 1983: "Geometric Nonlinear Analysis of the Finite Element Method of Shell [sic]"]

[Text] Abstract: Geometric nonlinear stiffness matrices for shells are derived. The programming method making the originally complex calculation quite simple, is given. Some numerical examples are also given.

I. Preface

Owing to developments in aircraft and space technology, thin wall panels and shell structures are used in great quantities. In order to further reduce the weight of these structures, people have been prompted to do much experimental analysis and theoretical research on the characteristics of these structures. For certain practical problems, the linear theory fits well with experimental results. A large number of problems (great structural deformation, lateral stability, hypercurvature analysis, and the effects of defects), however, must still be studied with regard to their geometric nonlinear behavior. The finite element method has many advantages when used in geometric nonlinear analysis and is a very effective tool for resolving complicated structures.

This paper takes oblate shell elements as representatives to produce geometric nonlinear stiff matrix formulae that do not rely on the interpolation function of a particular element, as well as methods for writing routines. This allows originally complex calculations to become rather more convenient. Finally, numerical results for a flattened cylinder and for an oblate spheroid are provided.

II. A Nonlinear Element Stiff Matrix

Different theories about shells produce different displacement--strain relations. Using the displacement--strain relation of the flat shell large displacement given in Reference 3:

$$
\begin{cases}
\varepsilon_{xx} = \dfrac{\partial u}{\partial x} + \dfrac{w}{R_{11}} - z\dfrac{\partial^2 w}{\partial x^2} + \dfrac{1}{2}\left(\dfrac{\partial w}{\partial x}\right)^2, \\
\varepsilon_{yy} = \dfrac{\partial v}{\partial y} + \dfrac{w}{R_{22}} - z\dfrac{\partial^2 w}{\partial y^2} + \dfrac{1}{2}\left(\dfrac{\partial w}{\partial y}\right)^2, \\
r_{xy} = \dfrac{\partial u}{\partial y} + \dfrac{\partial v}{\partial x} + \dfrac{2w}{R_{12}} - 2z\dfrac{\partial^2 w}{\partial x \partial y} + \dfrac{\partial w}{\partial x}\dfrac{\partial w}{\partial y},
\end{cases} \tag{1}
$$

where R_{11} is the principal curvature radius of the x direction, R_{22} is the principal curvature radius of the y direction, and R_{12} is the hybrid curvature radius.

If the material is evenly isotropic, the elastic matrix is

$$
D = \frac{E}{1-\nu^2}\begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \dfrac{1-\nu}{2} \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} & 0 \\ d_{21} & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix}. \tag{2}
$$

Based on Reference 6, the interpolation function for the element $\Omega^{(e)}$ is found to be

$$
\begin{cases}
u = \lfloor N_1 \rfloor B_1 \{u^{(e)}\}, \\
v = \lfloor N_2 \rfloor B_2 \{v^{(e)}\}, \\
w = \lfloor N_3 \rfloor B_3 \{w^{(e)}\},
\end{cases} \tag{3}
$$

where $\lfloor \quad \rfloor$ indicate row vectors, $\{ \quad \}$ indicate column vectors, $\lfloor N_i \rfloor$ is the term constituted row vector of the interpolation polynomial, $\{u^{(e)}\}$, $\{v^{(e)}\}$, $\{w^{(e)}\}$ is the partial nodal parameter constituted column vector for element $\Omega^{(e)}$, B_i is the element interpolated function, and the matrix (i = 1, 2, 3) is determined by the element nodal point coordinates and the nodal point parameters.

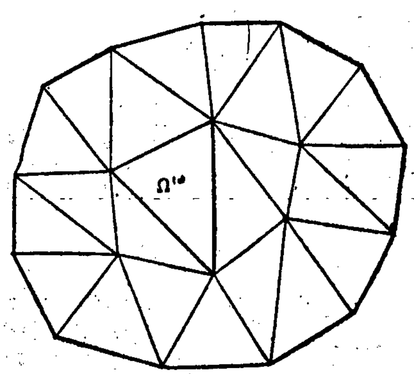


Figure 1. Element Dissection

Based on the stress-strain relation, the strain on element $\Omega^{(e)}$ can be varied to obtain the stiff matrix for the elastic large deformation (large displacement) small strain of a flat shell element as

$$K^{(e)} = K_1^{(e)} + K_2^{(e)} + K_3^{(e)},$$

$$K_1^{(e)} = \begin{bmatrix} k_{11}^{(1)} & & \text{对} \\ k_{21}^{(1)} & k_{22}^{(1)} & \text{称} \\ k_{31}^{(1)} & k_{32}^{(1)} & k_{33}^{(1)} \end{bmatrix}, \quad K_2^{(e)} = \begin{bmatrix} 0 & & \text{对} \\ 0 & 0 & \text{称} \\ k_{31}^{(2)} & k_{32}^{(2)} & k_{33}^{(2)} \end{bmatrix}, \tag{4}$$

$$K_3^{(e)} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & k_{33}^{(3)} \end{bmatrix}, \tag{5}$$

where

$K_1{}^{(e)}$--linear stiff matrix,

$K_2{}^{(e)}$--first order stiff matrix, each element of which is the linear homogeneous function of the element nodal point parameters,

$K_3{}^{(e)}$--second order stiff matrix, each element of which is the second homogeneous function of the element nodal point parameters.

Because the expansion of each element in the geometric nonlinear stiff matrix (4) is very lengthy and overelaborate, implementation in a program is a better method.[6] The calculation formulae that we adopted were general, but at the same time are still particular. In order to shorten things, we give here just a few submatrices, so for detailed formulae see Reference 6. For example:

$$k_{11}^{(1)} = B_1^T \iint_{\Omega^{(e)}} h \left(d_{11} \frac{\partial\{N_1\}}{\partial x} \frac{\partial\lfloor N_1 \rfloor}{\partial x} + d_{33} \frac{\partial\{N_1\}}{\partial y} \frac{\partial\lfloor N_1 \rfloor}{\partial y} \right) dx dy B_1, \tag{6}$$

$$\begin{aligned} k_{31}^{(2)} = B_3^T \iint_{\Omega^{(e)}} \frac{h}{2} \Bigg[& d_{11} \frac{\partial w}{\partial x} \frac{\partial\{N_3\}}{\partial x} \frac{\partial\lfloor N_1 \rfloor}{\partial x} + d_{12} \frac{\partial w}{\partial y} \frac{\partial\{N_3\}}{\partial y} \frac{\partial\lfloor N_1 \rfloor}{\partial x} \\ & + d_{33} \left(\frac{\partial w}{\partial x} \frac{\partial\{N_3\}}{\partial y} \frac{\partial\lfloor N_1 \rfloor}{\partial y} + \frac{\partial w}{\partial y} \frac{\partial\{N_3\}}{\partial x} \frac{\partial\lfloor N_1 \rfloor}{\partial y} \right) \Bigg] dx dy B_1, \end{aligned} \tag{7}$$

$$\begin{aligned} k_{33}^{(3)} = B_3^T \iint_{\Omega^{(e)}} h \Bigg\{ & \frac{d_{11}}{2} \left(\frac{\partial w}{\partial x} \right)^2 \frac{\partial\{N_3\}}{\partial x} \frac{\partial\lfloor N_3 \rfloor}{\partial x} + \frac{d_{22}}{2} \left(\frac{\partial w}{\partial y} \right)^2 \frac{\partial\{N_3\}}{\partial y} \frac{\partial\lfloor N_3 \rfloor}{\partial y} \\ & + \frac{d_{12} + 2d_{33}}{2} \Bigg[\frac{1}{3} \left(\frac{\partial w}{\partial x} \right)^2 \frac{\partial\{N_3\}}{\partial y} \frac{\partial\lfloor N_3 \rfloor}{\partial y} \\ & + \frac{1}{3} \left(\frac{\partial w}{\partial y} \right)^2 \frac{\partial\{N_3\}}{\partial x} \frac{\partial\lfloor N_3 \rfloor}{\partial x} + \frac{2}{3} \frac{\partial w}{\partial x} \frac{\partial w}{\partial y} \left(\frac{\partial\{N_3\}}{\partial y} \frac{\partial\lfloor N_3 \rfloor}{\partial x} \right. \\ & \left. + \frac{\partial\{N_3\}}{\partial x} \frac{\partial\lfloor N_3 \rfloor}{\partial y} \right) \Bigg] \Bigg\} dx dy B_3, \end{aligned} \tag{8}$$

where h is the element depth (assuming it is layered), B_i^T is the transposed matrix (i = 1, 2, 3) of the matrix B_i, and under normal conditions, $B_1 = B_2$, and $\lfloor N_i \rfloor = \lfloor N_i \rfloor$. One can see from Equations (4) through (8) that this method of matrix representation is more distinct and clearer than using subscript notation (Reference 2, pp 246-247). Overall formation and linear analytical conditions are the same.

III. Program Techniques

One can see from Equations (7) and (8) that if calculations for the nonlinear element matrix use the method for general handling of linear problems (term-wise expanded calculations), then each element in the nonlinear portion ($K_2^{(e)}$ and $K_3^{(e)}$ is very tedious. To overcome this difficulty, we have written routines using the method proposed in Reference 6. The chief attributes of this method are: automatically selects element interpolation functions,[3] based on the element nodal point values and nodal point parameter types, while $\lfloor N_i \rfloor$ is always composed of terms of a polynomial (or is changed to this format), forming a computer oriented unified calculation formula that uses an analytical method to derive and integrate, and that produces a nonlinear element stiff matrix. One can see from Equations (6) through (8) that a typical derivation included in the calculation of Equation (4) is

$$\frac{\partial \lfloor N_i \rfloor}{\partial t} \ \& \ \frac{\partial^2 \lfloor N_3 \rfloor}{\partial s \partial t} \qquad (t, s = x, y, \ i = 1, 2, 3). \tag{9}$$

Included typical integrations are

$$\iint_{\Omega^{(e)}} \varphi_1 \{P\} \lfloor Q \rfloor dxdy \left(\& \iint_{\Omega^{(e)}} \frac{\partial \{N_1\}}{\partial x} \frac{\partial \lfloor N_1 \rfloor}{\partial y} dxdy \right), \tag{10}$$

$$\iint_{\Omega^{(e)}} \varphi_2 \{P\} \lfloor Q \rfloor dxdy \left(\& \iint_{\Omega^{(e)}} \frac{\partial w}{\partial x} \frac{\partial \{N_3\}}{\partial x} \frac{\partial \lfloor N_1 \rfloor}{\partial x} dxdy \right), \tag{11}$$

$$\iint_{\Omega^{(e)}} \varphi_3 \{P\} \lfloor Q \rfloor dxdy \left(\& \iint_{\Omega^{(e)}} \left(\frac{\partial w}{\partial x}\right)^2 \frac{\partial \{N_3\}}{\partial x} \frac{\partial \lfloor N_3 \rfloor}{\partial x} dxdy \right), \tag{12}$$

where $\{P\}$ and $\lfloor Q \rfloor$ are the column and row vectors making up the terms in the polynomial, φ_1 is the constant not related to the element partial nodal point parameters, φ_2 is the linear homogeneous function of the element partial nodal point parameters, φ_3, and φ_3 is the secondary homogeneous function for the element partial nodal point parameters. If element $\Omega^{(e)}$ is of variable thickness, then φ_1, φ_2, φ_3 are also thickness functions

The calculation of Equation (9) can be summed up as

$$\begin{cases} \dfrac{\partial}{\partial x} x^m y^n = m x^{m-1} y^n, \\ \dfrac{\partial}{\partial y} x^m y^n = n x^m y^{n-1}, \end{cases} \qquad (m, n \geqslant 0). \tag{13}$$

Therefore, it is very easy for the computer to implement this kind of derivation operation.

The integration of each element in Equations (10) through (12) can be summed up as

$$\iint_{\Omega^{(e)}} x^m y^n dxdy \quad (m, n \geqslant 0). \tag{14}$$

As for elements of different shapes, Equation (14) is handled through different integration subroutines, triangular elements, calculation under integral transformation to barycentric coordinates (area coordinates), and the integral calculated in the principal axis coordinate system.

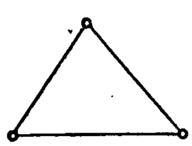
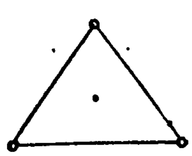
When comparing nonlinear analysis to linear analysis, the number of calculations for element stiff matrices is greatly increased, while in the solution process the calculations must be made over and over again, so saving calculation time becomes very important. For this purpose, saving calculation results from Equation (14) in a reflected [?] (xianghui [4161 6540]) triangle to obtain

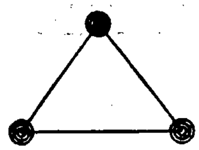
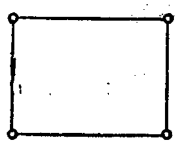
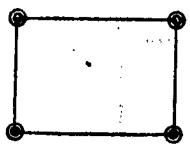
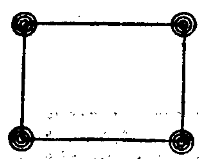
$$\begin{array}{c} 1 \\ x \quad y \\ x^2 \quad xy \quad y^2 \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ x^m \; x^{m-1}y \cdots\cdots xy^{m-1} \; y^m, \end{array} \qquad \begin{array}{c} 1 \\ x^2 \quad y^2 \\ x^4 \quad x^2y^2 \quad y^4 \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ x^{2m} \; x^{2m-2}y^2 \cdots\cdots x^2y^{2m-2} \; y^{2m}. \end{array}$$

Triangular elements Square elements

When integrating the first appearance of $x^m y^n$, roll-in the integration subroutines and save the results of the calculations in the order described above, then when the integration of this term appears repeatedly it need not be recalculated. Due to the symmetry of the stiff matrix, lower triangular elements can be calculated. As for the formation of $\underline{N_i}$ and B_i $(i = 1, 2, 3)$, see Reference 6 and 8 for the data handling of derivation and integration of the polynomial. We will not discuss it further here.

It is worth pointing out that when increasing the types of new elements that can be done by only expanding the functions of the subroutines for Equations (3) and (14), while the rest of the routines will need no further alteration. Our routines have produced triangular portions and square portions (including plane shell elements ellipsoid shell elements, and cylindrical [?] (GUI) [2710] shell elements), and there is a 6 x 3 element type, the nodal parameters of which are as follows:

Element shape	Nodal parameters (degree of freedom)	Degree of freedom
	$u \quad v \quad w$ $\theta_x = \frac{\partial w}{\partial y} \quad \theta_y = -\frac{\partial w}{\partial x}$	15
	$u \quad v \quad w$ $\theta_x \quad \theta_y \quad w_{\text{心}}$	16

Element shape	Nodal parameters (degree of freedom)	Degree of freedom
	$u \quad \frac{\partial u}{\partial x} \quad \frac{\partial u}{\partial y}$ $v \quad \frac{\partial v}{\partial x} \quad \frac{\partial v}{\partial y}$ $w \quad \frac{\partial w}{\partial x} \quad \frac{\partial w}{\partial y} \quad \frac{\partial^2 w}{\partial x^2} \quad \frac{\partial^2 w}{\partial y^2} \quad \frac{\partial^2 w}{\partial x \partial y}$	36
	$u \quad v \quad w$ $\theta_x \quad \theta_y$	20
	$u \quad v \quad w$ $\frac{\partial w}{\partial x} \quad \frac{\partial w}{\partial y} \quad \frac{\partial^2 w}{\partial x \partial y}$	24
	$u \quad \frac{\partial u}{\partial x} \quad \frac{\partial u}{\partial y}$ $v \quad \frac{\partial v}{\partial x} \quad \frac{\partial v}{\partial y}$ $w \quad \frac{\partial w}{\partial x} \quad \frac{\partial w}{\partial y} \quad \frac{\partial^2 w}{\partial x \partial y}$	40

The remaining types of nodal point parameters are not listed one by one here.

IV. Flowchart for Nonlinear Element Rigid Matrix Routines

Subroutine A_1:

↓

Form the matrix $B_i (i = 1, 2, 3)$

↓ Return

Subroutine A_2:

↓

Form the column vector $\{N_i\} (i = 1,2,3)$

↓ Return

Subroutine A_3:

↓

Calculate the derivitive value $(i=1,2,3)$ of $\lfloor N_i \rfloor$

↓ Return

Subroutine A_4:

↓

Calculate $\iint_{\Omega^{(e)}} \varphi_i\{P\}\lfloor Q \rfloor dxdy (i=1,2,3)$

↓ Return

Subroutine A_5:

↓

Calculate $\iint_{\Omega^{(e)}} x^m y^n dxdy$

↓ Return

Subroutine A_6:

↓

Calculate $B_i^T S B_i$, also send the result to the assigned position; S is the symmetric matrix, remaining triangle; (i= 1,2,3)

↓ Return

Subroutine A_7:

↓

Calculate $B_i^T R B_j$, also send the result to the assigned position; R is a square matrix of a rectangular matrix; (i=1,2,3;j=1,2,3)

↓ Return

where $\lfloor N_1 \rfloor = \lfloor N_2 \rfloor$, $B_1 = B_2$.

The main flowchart

↓

Form the element nodal point values, nodal point parameter types, and form the basic data for calculating the element stiff matrix.

↓

call A_2, fom$\lfloor N_1 \rfloor$;call A_1,form B_1

↓

↓

Call A_3, calculate $\frac{\partial\lfloor N_1\rfloor}{\partial x}$、$\frac{\partial\lfloor N_1\rfloor}{\partial y}$; call A_4、A_5, calculate $\iint_{\Omega^{(e)}} \frac{\partial\{N_1\}}{\partial x}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial\{N_1\}}{\partial y}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial\{N_1\}}{\partial x}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$.

↓

Call A_6, calculate $k_{11}^{(1)}$、$k_{22}^{(1)}$; call A_7, calculate $k_{12}^{(1)}$.

↓

Call A_2, form $\lfloor N_3\rfloor$; call A_1, form B_3; call A_3, calculate $\frac{\partial^2\lfloor N_3\rfloor}{\partial x^2}$、$\frac{\partial^2\lfloor N_3\rfloor}{\partial y^2}$、$\frac{\partial^2\lfloor N_3\rfloor}{\partial x\partial y}$

↓

Call A_4、A_5, calculate $\iint_{\Omega^{(e)}} \frac{\partial^2\{N_3\}}{\partial x^2}\frac{\partial^2\lfloor N_3\rfloor}{\partial x^2}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial^2\{N_3\}}{\partial y^2}\frac{\partial^2\lfloor N_3\rfloor}{\partial y^2}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial^2\{N_3\}}{\partial x\partial y}\frac{\partial^2\lfloor N_3\rfloor}{\partial x\partial y}dxdy$.

↓

Discriminant $\frac{1}{|R_{11}|}+\frac{1}{|R_{22}|}+\frac{1}{|R_{12}|}\neq 0$ — (=) → to "Call A_6, calculate $k_{33}^{(1)}$"

↓ ≠

Call A_4、A_5, calculate $\iint_{\Omega^{(e)}} \{N_3\}\lfloor N_3\rfloor dxdy$、$\iint_{\Omega^{(e)}} \{N_3\}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} \{N_3\}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$

↓

Call A_6, calculate $k_{33}^{(1)}$; call A_7, calculate $k_{31}^{(1)}$、$k_{32}^{(1)}$

↓ ($K_1^{(e)}$ calculation completed)

Call A_3, calculate $\frac{\partial\lfloor N_3\rfloor}{\partial x}$、$\frac{\partial\lfloor N_3\rfloor}{\partial y}$

↓

Call A_4、A_5, calculate
$\iint_{\Omega^{(e)}} F_{11}\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_3\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} F_{22}\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_3\rfloor}{\partial y}dxdy$、$\iint_{\Omega^{(e)}} F_{12}\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_3\rfloor}{\partial y}dxdy$,
$\iint_{\Omega^{(e)}} \frac{\partial w}{\partial x}\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial w}{\partial x}\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial w}{\partial x}\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$,
$\iint_{\Omega^{(e)}} \frac{\partial w}{\partial y}\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial w}{\partial y}\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$、$\iint_{\Omega^{(e)}} \frac{\partial w}{\partial y}\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$.

↓

Discriminant: $\frac{1}{|R_{11}|}+\frac{1}{|R_{22}|}+\frac{1}{|R_{12}|} \neq 0$ (=: go to Call A_6 box)

$\downarrow \neq$

Call A_4, A_5, calculate $\iint_{\Omega^{(e)}} \frac{\partial w}{\partial x}\{N_3\}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$, $\iint_{\Omega^{(e)}} \frac{\partial w}{\partial x}\{N_3\}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$, $\iint_{\Omega^{(e)}} \frac{\partial w}{\partial y}\{N_3\}\frac{\partial\lfloor N_1\rfloor}{\partial x}dxdy$, $\iint_{\Omega^{(e)}} \frac{\partial w}{\partial y}\{N_3\}\frac{\partial\lfloor N_1\rfloor}{\partial y}dxdy$

$\downarrow$

Call A_6, calculate $k_{31}^{(2)}$; call A_7, calculate $k_{31}^{(2)}$, $k_{33}^{(2)}$.

$\downarrow$ ($K_2^{(e)}$ calculation completed)

Call A_4, A_5, calculate $\iint_{\Omega^{(e)}} \left(\frac{\partial w}{\partial x}\right)^2\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_3\rfloor}{\partial x}dxdy$, $\iint_{\Omega^{(e)}} \left(\frac{\partial w}{\partial x}\right)^2\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_3\rfloor}{\partial y}dxdy$, $\iint_{\Omega^{(e)}} \left(\frac{\partial w}{\partial y}\right)^2\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_3\rfloor}{\partial x}dxdy$, $\iint_{\Omega^{(e)}} \left(\frac{\partial w}{\partial y}\right)^2\frac{\partial\{N_3\}}{\partial y}\frac{\partial\lfloor N_3\rfloor}{\partial y}dxdy$, $\iint_{\Omega^{(e)}} \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\frac{\partial\{N_3\}}{\partial x}\frac{\partial\lfloor N_3\rfloor}{\partial y}dxdy$.

$\downarrow$

Call A_6, calculate $k_{33}^{(3)}$.

$\downarrow$ ($K_3^{(e)}$ calculation completed)

The entire nonlinear element stiff matrix is complete

$\downarrow$

Return

V. Results and Analysis of Numerical Values

(1) The basic program

Formation of geometric nonlinear general stiff matrices is the same as the linear superimposed process. Based on nodal point parameters transformation formulae,[5] transform the element stiff matrix (4) under partial nodal point parameters to an element stiff matrix with overall nodal point parameters, then based on element nodal point coding, overlaying onto an overall stiff matrix. The equilibrium equation for a geometric nonlinear elastic shell is

$$(K_1 + K_2(\Delta) + K_3(\Delta))\{\Delta\} = \{P\}, \tag{15}$$

where K_1--linear stiff matrix; $K_2(\Delta)$--first degree stiff matrix; $K_3(\Delta)$--second degree stiff matrix; $\{\Delta\}$--column vector for overall nodal point parameters (degree of freedom); and $\{P\}$--load column vector.

Equation (15) can be solved with various iterative methods, and often used iterative methods are the direct iteration method, the Newton-Raphson method, and the incremental method. Here, the direct iteration method is used. Its iterative format is

$$\{\triangle_k^{(j)}\} = K_1^{-1}(\lambda_k\{P\} - \{F(\triangle_k^{(j-1)})\}), \tag{16}$$

$$\{F(\triangle_k^{(j-1)})\} = (K_2(\triangle_k^{(j-1)}) + K_3(\triangle_k^{(j-1)}))\{\triangle_k^{(j-1)}\}. \tag{17}$$

The initial values are:

$$\{\triangle_1^{(0)}\} = \lambda_1 K_1^{-1}\{P\},$$

$$\{\triangle_k^{(0)}\} = \{\triangle_{k-1}^{(*)}\}. \tag{18}$$

The iteration convergence discriminant standard is taken as (19)

$$\max_l \left| \frac{\{\triangle_k^{(j)}\}_l - \{\triangle_k^{(j-1)}\}_l}{\{\triangle_k^{(j)}\}_l} \right| < \varepsilon = 10^{-2}, \tag{20}$$

where λ_k--load increase factor ($k \geqslant 1$), and the subscript k is related to the load increase factor λ_k, the superscript j is the iterative frequency of λ_k, and the subscript ℓ indicates the ℓ component of $\{\Delta_k^{(j)}\}$.

The essentials of the calculation of the direct iteration method are

(i) generate K_1 and $\{P\}$;
(ii) resolve K_1 (change to the square root method);
(iii) calculate $\{F(\Delta_k{}^{(j)}\}$ the method being similar to calculating the equivalent uniform load for physical strength;
(iv) by resubstitution find the solution $\{\Delta_k{}^{(j)}\}$ to Equation (6);
(v) Equation (20) does not satisfy, jump to (iii); Equation (20) does satisfy, alter λ_k, then jump to (iii).

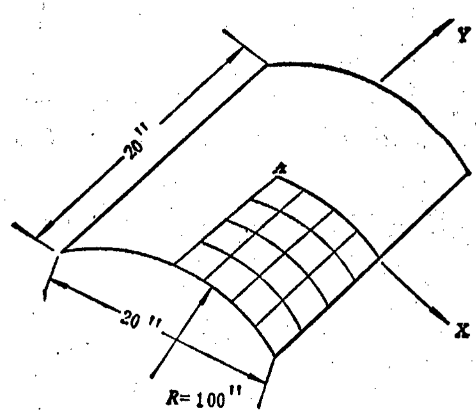


Figure 2. Elliptical Surface of a Cylinder

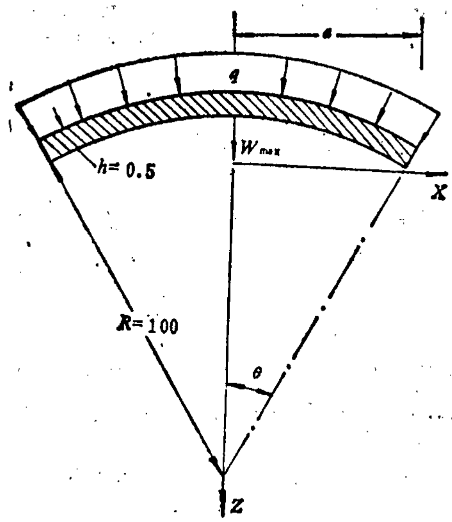


Figure 3. Elliptical Surface of a Spherical Section

$E = 3 \times 10^4$ $\nu = 0.3$ $q = E\left(\frac{h}{R\sin\theta}\right)^4$

$\theta = 7.1°$

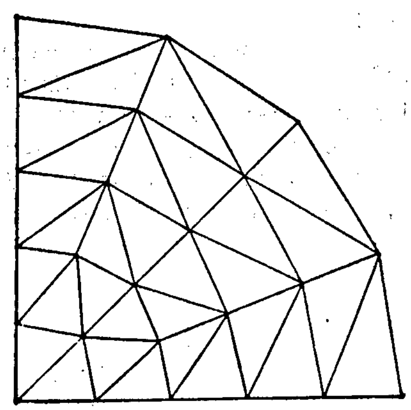


Figure 4. Finite Element Grid

(2) Calculation of a peripherally fixed elliptical surface of a cylinder

q = 0.04 lbs/sq inch
h = 0.125 inch
E = 450,000 lbs/sq inch
v = 0.3

Calculating one-fourth of an elliptical surface of a cylinder, partition that into 4 x 4, calculate using the 16 square elements, then calculate 32 triangular elements, and the two groups of square elements will be similar in type, while the iterative initial load will not be the same, the results being the same as those in Reference 2 (see Table 1).

Table 1.

λ_k	$(w_k)_A$	j Iteration frequency	$(w_k)_A$	j Iteration frequency	$(w_k)_A$	j Iteration frequency
1	0.117×10^{-1}	3			0.116×10^{-1}	2
2	0.249×10^{-1}	4			0.246×10^{-1}	4
3	0.402×10^{-1}	4			0.397×10^{-1}	4
4	0.591×10^{-1}	5			0.584×10^{-1}	5
5	0.865×10^{-1}	8	0.862×10^{-1}	8	0.855×10^{-1}	8
5.5			0.107	8		
6	0.137	13	0.136	10	0.138	14
6.4			0.167	9		
6.8			0.197	9		
7	0.209	13	0.208	4	0.213	13
7.1			0.213	2		
Dissection Type	Square elements 4 nodal points 20 degrees freedom		Square elements 4 nodal points 20 degrees freedom		Triangular elements 3 nodal points 15 degrees freedom	

(3) Calculation of a peripherally fixed elliptical surface of a sphere cap

Table 2

λ_k	$(w_k)_{max}$	j Iteration frequency	$(w_k)_{max}$	j Iteration frequency
1			0.299×10^{-1}	2
2			0.637×10^{-1}	4
3	0.934×10^{-1}	4	0.103	5
4			0.150	5
5			0.211	7
6	0.241	7	0.300	9
7	0.326	8	0.488	17
7.5	0.383	7		
8	0.464	9	0.784	15
8.5	0.583	12		
9	0.707	11		
10	0.858	8		
Element type	Triangular oblate shell		Triangular plane shell	
Linear results	0.265676×10^{-1}		0.283222×10^{-1}	

Computing triangular oblate shell elements and triangular plane shell elements, their difference will be least when their deformation is less. For large deformation, differences between the two will become greater as the load increases. The capability of plane shell elements to resist deformation is less than that of oblate shell elements. We can see from Table 2 that for relatively flat sphere cap shells, when doing linear analysis with plane shell elements the results are still better. The computational results for triangular oblate shell elements are the same as with Reference 4.

(4) Newton-Raphson iteration

In finite element geometric nonlinear analysis before critical loads is most often solved with Newton-Raphson iterative, direct iterative, and load incrementive methods, the basic form for which is the Newton-Raphson iteration. The general format for that may be written

$$\{\Delta_k^{(j+1)}\} = \{\Delta_k^{(j)}\} - K_T^{-1}(\Delta_k^{(j)})\{R(\Delta_k^{(j)})\}, \tag{21}$$

$$K_T(\Delta_k^{(j)}) = K_1 + 2K_2(\Delta_k^{(j)}) + 3K_3(\Delta_k^{(j)}), \tag{22}$$

$$\{R(\Delta_k^{(j)})\} = (K_1 + K_2(\Delta_k^{(j)}) + K_3(\Delta_k^{(j)}))\{\Delta_k^{(j)}\} - \lambda_k\{P\}, \tag{23}$$

where $K_T(\Delta)$ is called a tangential stiff matrix and is also the discriminant matrix for the critical load, because the row and column values for $K_T(\Delta)$ of the limit or ramification points are zero. Obviously, the formation of $K_T(\Delta)$ is the same as the overall stiff matrix. Because elemental nonlinear stiff matrices are formed by overlapping according to strict rules. If the load is not graded, the subscript k will not appear.

The advantages of the Newton-Raphson method are that it is broad in application and has a high speed of convergence (quadratic convergence), but there is a great deal of computation (each iteration must reform $K_T(\Delta)$, while requirements for the initial values of the iteration are strict.[9] Many correction plans have been proposed centering on relaxing the initial values, lowering the amount of calculation, and improving convergence speed, and one often used algorithm is to take $K_T(\Delta) = K_1$, called the Newton-Raphson correction method, where Equation (21) becomes

$$\{\Delta_k^{(j+1)}\} = \{\Delta_k^{(j)}\} - K_1^{-1}\{R(\Delta_k^{(j)})\}. \tag{24}$$

Substituting Equation (23) in Equation (24) we get

$$\begin{aligned}\{\Delta_k^{(j+1)}\} &= \{\Delta_k^{(j)}\} - K_1^{-1}[(K_1 + K_2(\Delta_k^{(j)}) + K_3(\Delta_k^{(j)}))\{\Delta_k^{(j)}\} - \lambda_k\{P\}] \\ &= -K_1^{-1}[(K_2(\Delta_k^{(j)}) + K_3(\Delta_k^{(j)}))\{\Delta_k^{(j)}\} - \lambda_k\{P\}].\end{aligned} \tag{25}$$

It follows that Equations (24) and (25) are the same as Equations (16) and (17). Therefore, the direct iteration method is the corrected Newton-Raphson iteration in a certain significance, and it clearly reduces the calculation time for each iteration. Theoretically, the original quadratic convergence drops to a linear convergence. If requirements for the precision of the

solution (see Equation (20)) are not strict, we can usually achieve the goal of a drop in the amount of overall calculation.

The load incrementive method is to divide the load into several incremental sums, to increment each load, and for the overall stiffness matrix to also use the corresponding approximation of the linear stiff matrix. Solving a linear problem, you obtain a displacement increment, then overlay each displacement increment to obtain the displacement that is finally required, the computational form for which may be written

$$\{\delta_k\} = \lambda_k(K_1 + K_2(\triangle_{k-1}) + K_3(\triangle_{k-1}))^{-1}\{P\}, \tag{26}$$

$$\{\triangle_k\} = \{\triangle_{k-1}\} + \{\delta_k\} = \sum_{i=0}^{k} \{\delta_i\} \qquad (\delta_0 = 0), \tag{27}$$

$$\lambda_0 = 0, \quad \sum_{i=0}^{M} \lambda_i = c_p, \tag{28}$$

where c_p is the given constant. This avoids the convergence problem that is generated by iterative solutions, but the accuracy is difficult to control. To ensure a certain degree of accuracy we must seek for each factor λ_i to be smaller, cause M to become greater, and consequently to expand the amount of computation. We can, at the same time that we increase λ_i (reducing M), insert an appropriate iteration correction causing a decrease in the overall amount of computation, as well as ensuring a certain precision in the solution.

It can be seen from Equations (21) and (22) that the Newton-Raphson method is not suited to use in calculating displacement in the vicinity of critical loads. For analysis of displacements in the vicinity of limit points and ramification points, the perturbation method is most often used.[7]

(5) Analysis of results

As the calculations for cylinder elliptic shells and oblate shells show, the direct iteration method is very effective for geometric nonlinear calculations before critical loads. Actually, it is just as pointed out above, that the direct iteration method is a corrected Newton-Raphson method. The calculation process also shows that when you compare a certain load that has been split into several increments to that load not so split, the overall calculation time for that not split up is less, and the convergence does not change. Because the tangential stiff matrices are similar (both are K_1), the results described above are quite predictable. Therefore, when there is a low level load, the amplitude of load increases can be greatly enlarged. In the calculation process of the two examples above, errors are basically in monotone descent, and it is only when using plane shell element approximation that there are occasional errors in the calculation process that are not monotone descending. When geometric nonlinearity is critical, iteration will generate erroneous oscillating motion, and convergent results can possibly not be obtained.[7] It can be seen in the process of calculation that when erroneous high amplitude oscillating motion is produced, the iterations will not

converge, and the calculation should be stopped or another method should be immediately taken up.

We can also see from the computational results of cylindrical elliptical shells that in the calculation of triangular elliptical shell elements and square elliptical shell elements, calculation precision and convergence speed are uniform. However, in the aspect of the amount of calculation, the former is much greater than the latter. Using triangular portions, not only is the quantity of elements double that of squares, but the time taken by each element is greater--it takes time to integrate triangular fields. Therefore, in geometric nonlinear analysis, we ought to use square elements more often and use triangular elements less.

For the computer programs used in this paper, we utilized a few general functional modules from the 1977-78 finite element universal routines of the Computer Center, Chinese Academy of Sciences. We gratefully thank the colleagues who took part in this work. We also express our gratitude to the one routine by Comrade Xiao Renshi [5135 0088 0099] of the joint unit of the Nanchang Plant No 320, used in this computer program.

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PHYSICAL SCIENCES

HOLOGRAPHIC NDT OF THIN TITANIUM PLATE DESCRIBED

Beijing XIYOU JINSHU [RARE METALS] in Chinese Vol 9 No 4, Jul 85 pp 58-61

[Article by Yang Ruixiang [2799 3843 4382]: "Nondestructive Testing of Internal Defects of Thin Titanium Plate With Laser Holography"]

[Text] I. Introduction

Holography is a technique for recording the amplitude and phase changes of an object on a photographic plate in the form of interference fringes. Because the holographic interference method can examine a component in the noncontact mode and is not bothered by complicated part shape or surface roughness, it has been widely used in nondestructive testing.[1-8]

In the rapidly developing aerospace industry, titanium and titanium alloy thin plates are used more and more but local delamination has been found in the production process of bonded titanium plates. Using ultrasonic methods, such defects are difficult to detect and large area delaminations with tightly closed edges can easily be missed. Other testing methods are also unsuccessful. We therefore developed a holographic method for detecting defects in thin titanium plates and tested several high temperature alloy plates.

II. Testing Equipment

The apparatus consists of a vibration-free table, a He-Ne laser, a beam elevator, three electronic shutters, a beam splitter, two beam expanders, a reflection mirror, a real time photographic plate, a real time developer and fixer, and an electrically controlled platform. The setup is shown in Figure 1, and the light path is shown in Figure 2.

Figure 1. Holographic Testing Apparatus

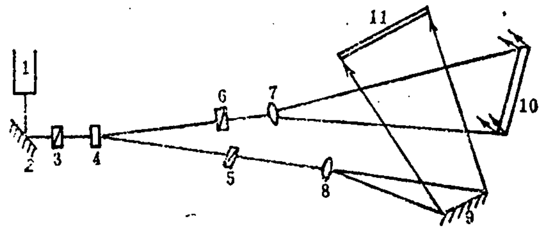

Figure 2. Schematic Diagram of the Light Path

Key:

1. Laser
2. Beam elevator
3. Shutter
4. Beam splitter

5,6. Shutter

7. Beam expander
8. Beam expander
9. Reflection mirror
10. Sample
11. Holographic plate

The details of the testing setup are as follows:

1. Laser. The laser used in the testing is a monochromatic, single mode laser with a stable output power. The coherence length of the laser is greater than the dimension of the test piece. We have used both ZWB-100 and JD-3 He-Ne lasers. The output power is monitored with a GG-1 laser power meter.

2. Beam elevator. The beam elevator adjusts the laser beam to the proper height and direction.

3. Electronic shutters. The electronic shutter controls the exposure time.

4. Beam splitter. The beam splitter divides the laser beam into an object beam and a reference beam and controls their ratio at $1/8 \sim 1/10$ on the holographic plate. The ratio of the object beam and the reference beam is measured with a light intensity meter and a light spot galvanometer assembly.

5.6. Electronic shutters. The shutters may be operated independently at the electronic control panel.

7. Beam expander. The beam expander 7 expands the incident laser beam uniformly to cover the test piece 10.

8. Beam expander. The beam expander 8 expands the incident laser beam uniformly to fill the reflection mirror 9.

9. Reflection mirror. The reference beam reflects at the mirror and fills the holographic plate 11.

10. Test specimens. Test piece No 1 is a titanium plate 2 mm thick and 150 x 150 mm^2 in area. Test piece No 2 is a titanium alloy plate 2 mm thick and 455 x 255 mm^2 in area. Test piece No 3 is a high temperature alloy plate 3 mm thick and 200 x 200 mm^2 in area.

11. Holographic plate. We used the Tianjin I type holographic plate to record the interference fringes.

During the test, a number of light shields were installed to keep the stray light out.

II. Testing Method

The nondestructive testing was made using an infrared thermal loading method. Large size titanium alloy plates were examined in sections. Thin titanium alloy plates were held with clamps to reduce the low frequency vibration. The principle of thermal loading NDT is as follows:

When the thin plate is heated and expands, the surface deforms slightly. If the load is applied properly and the plate is defect free, the surface deformation is regular and the corresponding interference fringes are a smooth set of curves. If the plate has internal defects, a proper loading will reveal anomalies of surface strain distribution. Such anomalies show up as irregularities in the interference fringes and are used to detect flaws.

The small surface deformation can be measured with two different methods:

(1) Real time method

In this method a hologram is first taken without load and the interference fringes on the loaded plate surface are then observed through the no-load hologram for any irregularity. The advantage is that only one hologram is needed to observe the surface condition at various load levels. It can rapidly and economically determine the required load level accurately. The major problem is that it requires an attachment that ensures a reproducible position of the hologram and the displacement cannot be more than a few wavelengths of light.

(2) Double exposure method

In this method, two holograms are taken on the same film with the object under two different loads. The two waves are then reconstructed. The addition of the two reconstructed waves leads to interference fringes and irregularities of the fringes are indications of internal flaws.

This method is immune to the difficulty of accurately repositioning the hologram and the problem of film shrinkage. The disadvantage is that one cannot observe the surface deformation at different load levels and it is more difficult to determine the load parameters.

In order to detect irregularities in the dense and indiscernable fringes, a fringe control technique is used. The hologram film is sensitized to improve the exposure speed and the quality of the hologram. The sensitization procedure is to immerse the film in a 5 percent triethanolamine solution for 10 seconds.

IV. Testing Results

Using an infrared lamp for the heating, defect fringes can be clearly seen in the real time method when the plate temperature is increased by 0.5-10°C and the reproducibility is good. Since flaws at different locations on the plate may not appear simultaneously at the same load, the experimental conditions must be carefully controlled and the hologram is then taken with the double exposure method.

Figures 3, 4, 5, and 6 are reconstructed pictures of defects in plate Nos 1, 2, and 3. The testing of plate No 2 was done in two steps and the results are shown in Figures 4 and 5, respectively. Figure 6 shows a defect in the high temperature alloy plate. The test results are in agreement with delamination detected by Lamb waves.

Figure 3. Hologram of Plate No 1

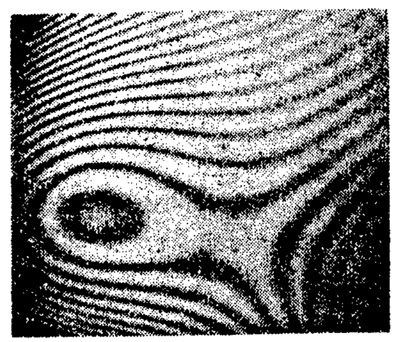

Figure 4. Hologram of Plate No 2

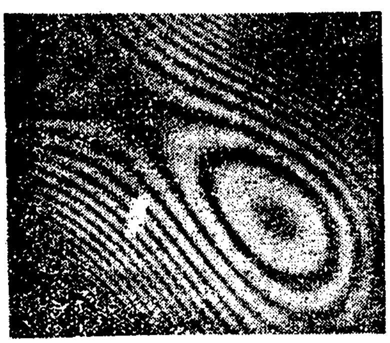

Figure 5. Hologram of a Different Location on No 2

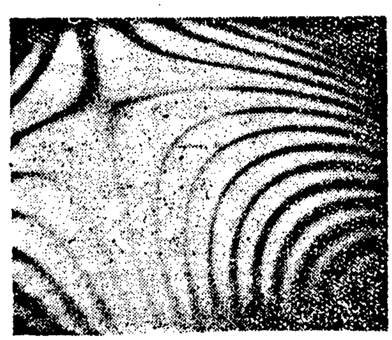

Figure 6. Hologram of Plate No 3

V. Discussion

1. Laser hologram can be used in the detection of delamination defects in titanium and titanium alloy thin plates.

We first inspected our samples with ultrasound and then used the laser hologram method on plates suspected to be defective. The holographic method confirmed the existence of defects and determined the defect location. To verify

the reliability of the holographic technique, we conducted the following experiments on plate No 1.

(1) By varying the experimental conditions, we observed fringe anomalies at the same location on the sample. On similar defect-free samples of the same thickness, no fringe anomalies were found.

(2) We confirmed the defect location found in the holographic testing with a SM-1 scanning apparatus.

(3) We sectioned the defected part of plate No 1 and analyzed the sectioned specimens metallographically and using SEM. Each specimen showed rod-like defects. On a 2 cm long specimen, several dozens of rod-like defects were found. The diameter of the rod was a few micrometers and 10 of the rod defects were 0.3-0.5 mm long. Figure 7 shows the defect shape. Sections of defect free samples revealed no defects. When the rod-like defect in Figure 7 was examined using a scanning electron microscope, the rods actually protruded above the surface. (See Figure 8)

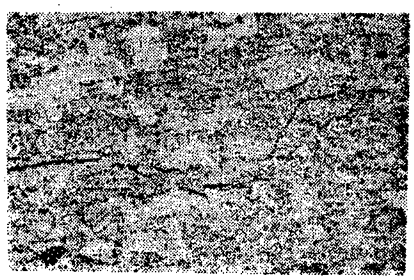

Figure 7. Metallographic Picture of Defect in Plate No 1 (x160)

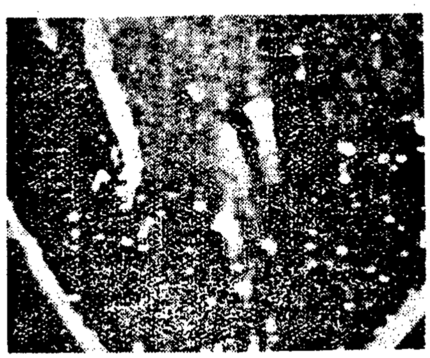

Figure 8. SEM Picture of Defect in Plate No 1 (x1800)

2. We have also tested delamination defects in high temperature alloy plates using the holographic method. Two of the plates were 2 mm thick and three plates were 3 mm thick. The plate area was 200 x 200 mm^2. The test results agreed with that using Lamb waves.

We have therefore demonstrated that laser holographic testing can detect delamination defects in press-formed titanium and titanium alloy plates and high temperature alloy plates. Because the holographic method has stringent

requirements on vibration, it is presently limited to laboratory use. Compared to ultrasonic and eddy current methods, the laser holographic method has a poorer efficiency and is more costly. However, if the presently used holographic film is replaced by a photoconductive thermoplastic film[9] or an industrial television camera, the inspection speed will be much improved.[10]

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9698/9365
CSO: 4008/1012

PHYSICAL SCIENCES

RING DEFECT OF GaAs STUDIED

Beijing XIYOU JINSHU [RARE METALS] in Chinese Vol 9 No 4, Jul 85 pp 21-23

[Article by Chen Jianbang [7115 1017 6721] and Zhang Guoli [1728 0948 0448]: "The Ring Defect of GaAs Crystals"]

[Text] I. Introduction

In recent years III-V compound semiconductor devices have attracted considerable attention for their applications in such areas as high-speed integrated circuits, dual heterojunction semiconductor lasers, integrated optics devices, microwave and optical communication, and fifth generation computers. The development of III-V semiconductor devices naturally requires a complete technology base for epitaxial growth. It requires high quality uniform epitaxial layer, uniform multilayer structures of a few hundred angstrom thickness and defect-free single crystal substrates. Such technology is a prerequisite producing high performance and durable semiconductor devices. In terms of the substrate, the single crystal should be large, the radial distribution of concentration should be uniform and the crystal should be free from defects. The crystal integrity and the elimination of defects are of great importance in the development of GaAs IC's.

Common defects in GaAs are dislocations, stacking faults, and precipitates. Etching with molten KOH often reveals the dislocation pits, and the number of dislocation pits is generally used as an indicator of the defect density of the single crystal. Recently we have often observed circular defects in chemically etched Si-doped GaAs single crystals grown in a horizontal boat. Some of these circular defects have an indented central part and resemble the shape of lunar mountains. We call them ring defects. In this article we describe in detail the detection method of ring defects and the results of electron probe analysis.

II. Experiment and Results

The GaAs single crystal grown with a horizontal boat is first cut perpendicular to the <100> direction into 1 mm thick slices, rough polished with No 302 grit corundum to remove the cut marks and then fine polished with No 306 grit corundum. They are then cleaned, etched with a chemical solution made from three parts sulphuric acid, one part hydrogen peroxide, and one part deionized

water, and then etched with 300°C molten KOH for 5 minutes. After the crystals are cleaned and dried at room temperature, they are examined under an optical microscope. The crystals show a number of small pits, as shown in Figure 1. In addition to the individual dislocation pits, most of the defects are circular in shape. The diameters are from 30-50 μm and the density is $2 \times 10^3 cm^{-2}$.

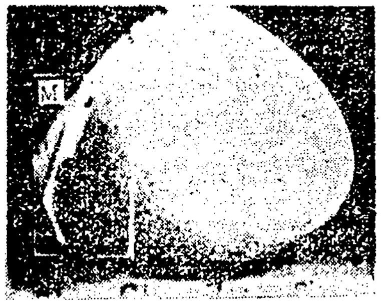


Figure 1. Macroscopic View of the Ring Defect

Figure 1 is the macroscopic view of the ring defect. When region M in Figure 1 is viewed under the microscope, the pictures are shown in Figure 2. The ring defects are labeled as R and the dislocation pits are labeled as D. In Figure 2(a) one can see that the dislocation pits are arranged along the <110> direction. The distribution of the ring defects is random and the ring defects also have a different appearance than that of dislocation pits, as shown in Figure 2(b). The morphological information obtained from X-ray reflection and transmission diffraction show that the ring defects are not related to the dislocation pits or the dislocation lines. In other words, they are not the tips of dislocation and they do not appear to spawn more dislocations. In fact, the number of dislocation pits is less in crystals with ring defects.

a

b

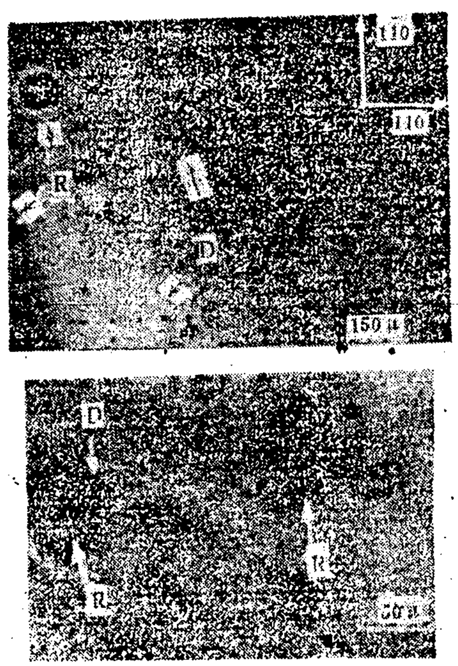
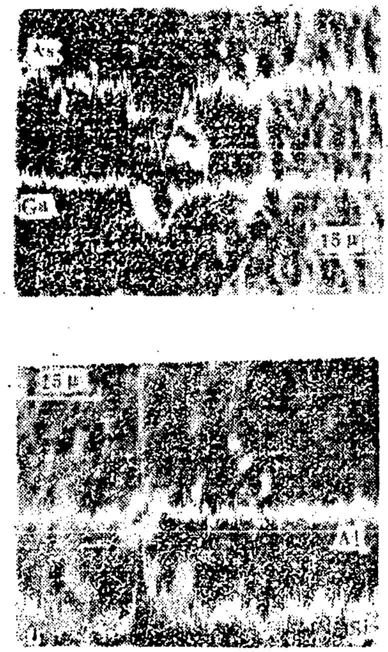


Figure 2. Optical Photomicrograph of Ring Defects



a

b

Figure 3. Electron Probe Analysis of the Central Indentation of the Ring Defect

We examined the ring defects with a JXA-50A electron probe operated at 25 kV. We find that the concentrations of Ga and As are lower at the center indentation of the ring defects, see Figure 3(a), whereas the concentrations of Al purity and Si are much higher than other places, see Figure 3(b).

Incidentally, it was reported in Reference 3 that ring defects (probably Si precipitates) and other forms of SiO_2, α-Ga_2O_3, and β-Al_2O_3 are often found when horizontally grown Si-GaAs single crystals are examined with a 1,000 kV SEM.

III. Analysis and Discussion

In the previous section we described the shape, size, and distribution of the ring defects and quantitative analysis shows that the ring defects contain impurity aluminum and silicon. We now present a simple analysis on the introduction of the impurity and the formation of the ring defects. Since the ring defects are observed in specimens cut directly from polished and chemically etched single crystals that have not been annealed or heat treated, the ring defects may be regarded as intrinsic; that is, the ring defects are primary flaws formed in the growth process of the single crystal. In our experiment we have polished away the top layer of crystals with a large number of ring defects and then chemically etched the polished surface. Almost all the ring defects disappeared. The distribution of the ring defects is therefore random. We may therefore speculate that the defect distribution may be related to the thermal field distribution in the crystal growth process and the formation of the defect may be directly related to silicon and aluminum impurities. Since the Al and Si contents of the starting materials (Ga and

As) are very low (less than 5 ppb) but the Al impurity content of the quartz boat and quartz tube is as high as 16 ppm, the Al impurity is most likely introduced by the quartz boat at high temperature. As for the Si impurity, the source is naturally the dopant itself and the SiO_2 in the quartz boat. From the quartz boat alone, the amount of Si concentration introduced at high temperature may reach $5 \times 10^{15}/cm^2$. The dopant and the effect of the thermal field make the Si impurity concentration even higher. We believe that the Al and Si impurities in the ring indentation are introduced by the quartz boat when the GaAs crystal is grown at high temperature. When the impurities reach a certain concentration in the thermal field, mixtures or oxides are formed. After chemical etching, irregular circular pits (i.e., "ring defects") are formed. These ring defects are very similar to those observed by Kaneno at the interface between GaAs and $Al_xGa_{1-x}As$ epitaxial layer, shown in Figure 4.

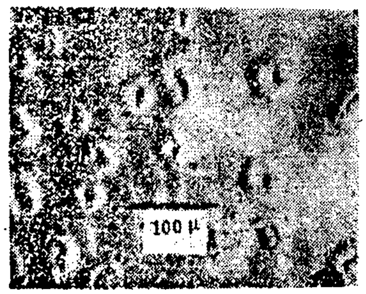


Figure 4. Ring Defects Observed by Kaneno, et al.

When they analyzed the central portion of the ring defect, they also found Al impurity. They believe that such defects are caused by the nonuniform mixture of Al_2O_3 and Ga_2O_3 in the liquid epitaxial growth. They also believe that the density of the ring defect is related to the contamination of the epitaxial atmosphere. If a semi-sealed device is used for the growth to reduce the oxygen contamination of the nitrogen atmosphere, the number of defects will be less.

As can be seen from Figures 2(a) and 4, the ring defects are very similar in shape. In both cases, Al impurity is detected at the central region of the defect. (We also detected Si.) Even though the impurity is introduced by different processes, it would be interesting to study the common features shared by the two defects and to explore the role of the Al impurity in the GaAs crystal. If we were to use our GaAs single crystal as a substrate for epitaxial growth, then it would be most likely to observe the type of ring defects observed by Kaneno, et al. at the epitaxy-substrate interface because the single crystal substrate already has such defects.

IV. Conclusion

When horizontally grown Si-GaAs single crystals are etched with molten KOH, we observed ring defects different from the usual dislocation pits. The defect diameter is about 30-50 μm and the density is $2 \times 10^3/cm^2$. Analysis shows that the central region of the defect has Al and Si impurities. The source of the Al impurity is believed to be the quartz boat because the Al

content of the quartz tube and quartz boat used in the crystal growth is as high as 16 ppm. The Si impurity naturally comes from the quartz boat and the dopant. To maintain the integrity of the GaAs single crystal, one must pay attention to the impurity content of the quartz boat used in the growth of the crystal in addition to the purity and the mixture ratio of the starting Ga and As materials.

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PHYSICAL SCIENCES

DESIGN OF NEW SYSTEM ARCHITECTURE WITH HYBRID REDUNDANCY (HCC)

Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese Vol 8, Jul 85 pp 314-320

[Article by Chen Tongzhao [7115 6639 3564] of the Xibei Institute of Telecommunications Engineering, manuscript received on 15 March 1983: "The Design of a New System Architecture With Hybrid Redundancy--HCC"]

[Text] Abstract: The current computer structure with hybrid redundancy (HCS) is analyzed and its problems are identified. A new hybrid redundancy system structure (HCC) is introduced. Compared to HCS, HCC recovers much more rapidly from failure. It can reuse modules cut off due to transient failure and thus becomes more reliable, neat in design, concise and easy to expand.

The fault-tolerance of a fault-tolerant computer is resulted from protective redundancy; i.e. redundant resources are used to improve the reliability of the system. Redundancy can be divided into hardware redundancy, software redundancy, information redundancy, and time redundancy. There are two basic types of hardware redundancy, i.e. static redundancy and dynamic redundancy. A new type of redundancy system--hybrid redundancy system--can be established by combining these two modes. A hybrid redundancy not only can shield the effect of any failure in time but also can automatically reconfigure and recover. The system not only is highly reliable but also can operate over long periods of time without failure. THerefore, it is widely used. For instance, this redundancy mode is used in the key components of the STAR computer such as TARP,[1] FTMP,[2] and SIFT.[3] The system, however, is highly software dependent. It is more appropriate to realize the hybrid redundancy system by hardware.

I. The HCS Structure and Its Problems

The hardware-based hybrid redundancy system introduced in References 4 and 5 is controlled by the switching component. In this paper it is denoted as HCS (Hybrid redundancy system Controlled by Switch). The system has N + S identical modules. N working modules form a "core" where N is an odd number. The remaining S modules are used as spares. These spares may or may not be powered. This system is denoted as H(N,S) in this paper.

The system has a voter which determines its output by majority. When the output of more than (N + 1)/2 of the working modules is 1(0), the output of

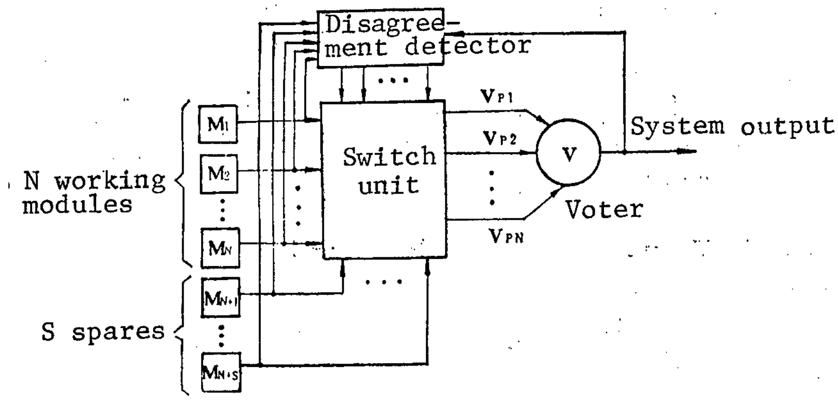

Figure 1. Principle of the HCS Structure

the system is 1(0). When the system is in operation, the disagreement detector is used to compare the output of the core modules and that of the system. Based on the result, the disagreement detector will inform the switch unit to replace modules inconsistent with the majority with the spares. The system continues to replace failed modules with the spares until all of them are in use. Then, the system becomes a simple majority voting system. The spare parts may also fail. The failure, however, cannot be detected until the spares are replaced to work as core modules. In this paper the voter, switch, and disagreement detector is abbreviated as VSD. Vpi is used to express the i^{th} position of the voter.

In general, VSD always becomes more complex with increasing S. Its failure rate will increase and the effect of VSD on the reliability of the system also goes up. Hence, VSD design is the focal point in the design of a hybrid redundancy system. The reliability of the entire system can be improved only when the VSD can be realized in a concise and reliable manner.

Based on the principle described above, an H(3,2) system was designed and reported in Reference 5. It was specifically analyzed and recognized to have the following major deficiencies.

(1) The VSD is relatively complicated. Furthermore, its complexity increases rapidly with increasing number of spares. It is difficult to make it reliable.

(2) The switch delay is significant. The delay is generally of the order of $D_0 \doteq 10 + 2(N + S)$. This limits the timing cycle and also slows down system recovery.

(3) Physically, the VSD is located between the module output and system output, affecting the rate of information transfer.

(4) It is very difficult to reuse modules cut off due to transient failure. Based on a great deal of statistical analyses, the majority of failure is transient.

A detailed analysis on the system with the HCS structure is performed from the angle of reliability.

Mathematical Model of Reliability

In an H(N,S) system, let us assume that the reliability of a module follows an exponential distribution. Let us also assume that the failure rates of the working and spare modules are λ and μ. Their reliability functions are $R(t) = e^{-\lambda t}$, $Q(t) = e^{-\mu t}$, respectively. Based on reliability theory, the reliability of the system can be expressed as (proof omitted):

$$R(N,S)(T) = R^N(T)Q^S(T)\left[1 + \sum_{j=0}^{S-2}\binom{NK+S}{j+1}\left(\frac{1}{Q(T)} - 1\right)^{j+1} + \sum_{i=0}^{n}\binom{N}{i}\binom{NK+S}{S}\sum_{l=0}^{i}\frac{\binom{i}{l}(-1)^{i-l}}{\binom{Kl+S}{S}} \cdot \left\{\left(\frac{1}{Q^S(T)R^l(T)} - 1\right) - \sum_{j=0}^{S-2}\binom{Kl+S}{j+1}\left(\frac{1}{Q(T)} - 1\right)^{j+1}\right\}\right] \quad (1)$$

$$S > 1.$$

$$R(N,1)(T) = R^N(T)Q(T)\left[1 + (NK+1)\sum_{i=0}^{n}\binom{N}{i}\sum_{l=0}^{i}\binom{i}{l} \times \frac{(-1)^{i-l}}{(Kl+1)}\left(\frac{1}{Q(T)R^l(T)} - 1\right)\right] \quad (2)$$

$\binom{J}{m}$ represents taking m combinations out of J, $K = \frac{\lambda}{\mu}$, $n = \frac{N-1}{2}$. The effect of VSD is not considered in the above equation.

Based on equations (1) and (2), for a given number of total modules, the reliability of the system decreases with increasing N and decreasing S. To this end, in order to improve the system reliability, we must use more modules as spares and keep the core modules at three.

Effect of Recovery Rate on Reliability and MTFF (Mean Time to First Failure)

Although the reliability can be improved by using a redundancy method, however, there are always some fatal failures. The entire system will fail when these problems occur. The parameter C (coverage) is used to describe the effect of this type of failure. C is defined as the probability of the system to be able to recover and continue information processing without suffering any permanent loss of any basic information after a failure (of the working or spare module) occurs. C is called the recovery rate.

Based on equation (1), we can derive the following:

$$R_{(3,S)}(T) = R^3(T)Q^S(T)\Bigg[1 + \sum_{j=0}^{S-2}\left(\frac{1}{Q(T)} - 1\right)^{j+1} \cdot \frac{\prod_{i=1}^{S}(3K+i)}{(j+1)!}$$

$$\cdot \left[\frac{1}{\prod_{l=1}^{S-j-1}(3K+l)} + \frac{2}{(S-j-1)!} - \frac{3}{\prod_{l=1}^{S-j-1}(K+l)}\right]$$

$$- \frac{2}{S!}\prod_{j=1}^{S}(3K+j)\left(\frac{1}{Q^S(T)} - 1\right)$$

$$+ 3\prod_{j=1}^{S}\frac{(3K+j)}{(K+j)}\left(\frac{1}{Q^S(T)R(T)} - 1\right)\Bigg] \quad (3)$$

When the recovery rate C is considered, the reliability of the system $H_{(3,S)}$ is denoted as $R^*_{(3,S)}(T)$. Then we can prove that (proof omitted):

$$R^*_{(3,S)}(T) = R^3(T)Q^S(T)\Bigg[1 + \sum_{j=0}^{S-2}\left(\frac{1}{Q(T)} - 1\right)^{j+1} \cdot \frac{\prod_{i=1}^{S}(3K+i)}{(j+1)!}\Bigg[\frac{C^{j+1}}{\prod_{l=1}^{S-j-1}(3K+l)}$$

$$+ \frac{(3C-1)C^S}{(S-j-1)!} - \frac{3C^{S+1}}{\prod_{l=1}^{S-j-1}(K+l)}\Bigg]$$

$$- \frac{(3C-1)C^S}{S!}\prod_{j=1}^{S}(3K+j)\left(\frac{1}{Q^S(T)} - 1\right)$$

$$+ 3C^{S+1}\prod_{j=1}^{S}\frac{3K+j}{K+j}\left(\frac{1}{R(T)Q^S(T)} - 1\right)\Bigg] \quad S \geqslant 2 \quad (4)$$

$$R^*_{(3,1)}(T) = R^3(T)Q(T)\left[1 + \frac{3(3K+1)C^2}{K+1}\left(\frac{1}{R(T)Q(T)} - 1\right)\right.$$

$$\left. - (3K+1)(3C-1)C\left(\frac{1}{Q(T)} - 1\right)\right] \quad (5)$$

The following conclusions can be obtained based on a great deal of analyses:

(1) When C = 1, the reliability of the system always increases with increasing S. The rate of increase, however, is decreasing gradually.

(2) For specific values of $C < 1$, λ, μ, and T, S has an optimal value S_0. When $S = S_0$, $R^*_{(3,S)}(t) < R^*_{(3,S\ )}(T)$. For instance, let $\lambda = 10^{-5}$/hour, $\mu = 5 \times 10^{-6}$/hr, $T = 2 \times 10^4$ hr. When C = 0.990, 0.991, 0.992, 0.993, 0.994, 0.995, $S_0 = 3$. When C = 0.996, 0.997, 0.998, 0.999, $S_0 = 4$.

(3) The larger S is, the shorter the operating time becomes and the larger the effect of C on R is.

C has a similar effect on MTFF. When the effect of C is considered,

$$\mathrm{MTFF}^* = \int_0^\infty R^*_{(3,s)}(t)\,dt$$

$$\mathrm{MTFF}^* = \frac{1}{3\lambda + S\mu} + \sum_{j=0}^{S-2}\left[\frac{\prod_{i=1}^{S}(3K+i)}{(j+1)!}\left[\frac{C^{j+1}}{\prod_{l=1}^{S-j-1}(3K+l)} + \frac{(3C-1)C^S}{(S-j-1)!}\right.\right.$$

$$\left.\left. - \frac{3C^{S+1}}{\prod_{l=1}^{S-j-1}(K+l)}\right]\sum_{h=0}^{j+1}\frac{\binom{j+1}{h}(-1)^h}{3\lambda + (S-j-1+h)\mu}\right]$$

$$- \frac{(3C-1)C^S}{S!}\prod_{j=1}^{S}(3K+j)\left[\frac{1}{3\lambda} - \frac{1}{3\lambda + S\mu}\right]$$

$$+ 3C^{S+1}\prod_{j=1}^{S}\frac{3K+j}{K+j}\left(\frac{1}{2\lambda} - \frac{1}{3\lambda + S\mu}\right) \qquad S > 1 \tag{6}$$

$$\mathrm{MTFF}^* = \frac{1}{3\lambda + \mu} + \frac{3(3K+1)C^2}{K+1}\left(\frac{1}{2\lambda} - \frac{1}{3\lambda + \mu}\right)$$

$$- (3K+1)(3C-1)C\left(\frac{1}{3\lambda} - \frac{1}{3\lambda + \mu}\right) \quad S = 1 \tag{7}$$

This shows that we should maximize the probability of the VSD to perform the correct module switching in the design of a hybrid redundancy system. Therefore, it is necessary to conduct a fault-tolerance design of the VSD. To add equipment alone cannot improve the reliability of the system.

Effect of VSD on Reliability

Let us denote the reliability of VSD as $R_R(T)$. Let us assume that the reliability of a working structure consisting of 3 + S modules is $R_E(T)$. Then, the reliability of the system is:

$$R(T) = R_E(T) \cdot R_R(T), \tag{8}$$

Because $R_E(T) < 1, R(T) < R_R(T)$. The reliability of the VSD is the upper limit of the system reliability.

In addition, Reference 6 pointed out that in an $H_{(3,N-3)}$ system there is a critical value R_{CP} for the reliability of an individual module R_0 for a given N. When $R_0 < R_{CP}$ regardless of R_R, $R < R_0$. Similarly, there is a critical value R_R. When R_R is less than this critical value, regardless of R_0, $R < R_0$. In other words, when R_0 or R_R is less than its critical value, the system reliability cannot be improved by hybrid redundancy.

II. HCC Structure

In recent years, numerous experiments conducted in educational institutions and corporations showed that approximately 90 percent of the failures of computer systems in operation are transient failures. Transient failure seriously affects the reliability of the system. In a hybrid redundancy system, it should be possible to reuse modules cut off due to transient failure to fully utilize the resources to further improve the reliability of the system.

Basic Principle of the HCC Structure

Figure 2 shows the basic principle of the HCC structure. The control unit controls the reconfiguration and recovery of the system. The function of the control unit is to determine the failured modules when there is disagreement and to choose spares to replace failed modules according to a specific algorithm to create a new working structure. It starts the core modules and connects them to the appropriate voter positions. The connecting circuit is a simple array of control gates which is responsible for linking the N modules chosen by the control unit to the appropriate positions.

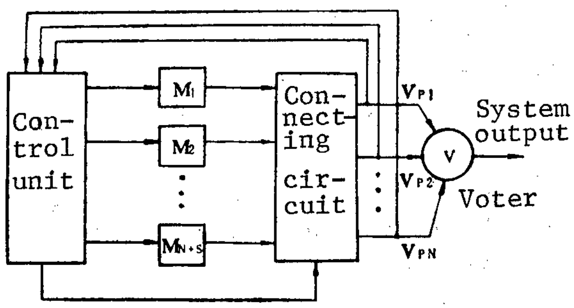

Figure 2. Principle of the HCC Structure

Based on the fact that the majority of failures is transient and the transient failure rate is gradually declining, modules failed within a specific time period are more susceptible to failure. A strategy to minimize the use of recently failed modules is adopted. The priority is to use those which did not fail recently or to use the spare modules which are not used recently. Each module is equipped with a counter with a suitable initial state. For instance, in the $H_{(3,N-3)}$ system, three counters are set at '0' and the remaining N-3 counters are 1, 2, 3, ···, N-3. The '0' counters correspond to the core modules. Whenever a module is replaced, counters corresponding to modules not included in the core will increase by 1. Counters corresponding to those modules selected are reset to 0. The module corresponding to the N-3 counter has priority to be chosen. This module has not recently been selected to enter the core.

The m modules selected to enter the core are positioned in the voter according to their physical sequence. The advantage of this arrangement is that the switching is simple. It is easy to determine the module positions in the voter. To detect disagreement, it is only required to compare the system

output to the line output without checking the output of each module. The number of disagreement detectors is reduced and the safety of the system is improved (line failure is also detected).

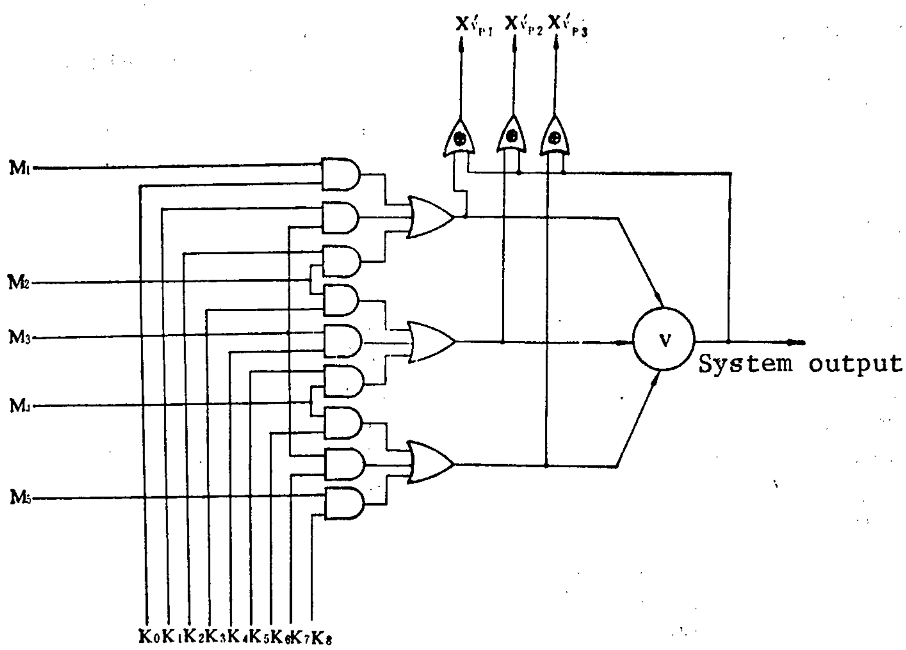

Figure 3. Connecting Circuit and Voter

Using the H(3,2) system as an example, the connecting circuit and voter are shown in Figures 3 and 4 [figure 4 not shown in original]. In the figures, M_i represents the output of the i^{th} module.

$(x_i)_0$, $(x_i)_1$, and $(x_i)_2$ represent counter contents 00, 01, and 10 corresponding to the i^{th} module, respectively. They represent that the module is in the core, is just replaced due to failure and is one of the two candidate reserves, respectively. The initial state of the counter, $(x_1)_0$, $(x_2)_0$, $(x_3)_0$, $(x_4)_1$, $(x_5)_2$, $(i = 1,2,3)$ is set to '0.' The PLA sends the module start signal s_1, s_2, s_3, and switch control signal K_0, K_3, K_5 to link the module output M_1, M_2, M_3 to the V_{P1}, V_{P2}, V_{P3} in the voter. When a disagreement is found, the system issues an interrupt request. There are two simple programs, i.e., interrupt process program and recovery program, in the system. The system may decide whether to respond to the interrupt request depending on the current task. For certain key tasks, they must be completed before responding to the interrupt request. The interrupt processing program stores all the necessary information to be recovered in each module in the memory or in certain registers. The control unit is triggered by the end of process signal to reconfigure the system. The control unit sends a new module start signal S_i and switch control signal K_j based on the new state to let the recovery program recover the system.

III. Comparison of the HCC Structure and HCS Structure

Compared to HCS, the HCC structure has the following improvements.

(1) Recovery is basically achieved by hardware. There is little dependence on software. The recovery is rapid. For instance, the delay between receiving a disagreement signal to sending an interrupt request is only 4.4 gate width in the aforementioned $H_{(3,2)}$ system. (The trigger is 1.4 gate width.) From receiving the end of process signal to sending the module start and switch control signal, there is a 3.4 gate width delay.

(2) It is not necessary to have additional tag for failed modules and for functional spares which saves hardware. In the HCS structure, however, it is required to use additional marker to label spare modules not powered.

(3) The data bus is basically separated from the switch control unit. There is little effect on the information transfer by switching.

(4) The design of VSD is simple and concise. It is easy to design a failure safe and completely self-detecting system.

(5) Modules cut off due to transient failure can conveniently be reused to improve the reliability of the system. To facilitate a detailed analysis, a parameter K is defined as the probability for the failed module to recover in a unit time period. According to Markov process and theory, the reliability functions of the aforementioned $H_{(3,2)}$ system are:

$$\frac{d}{dt} P_5(t) = -(3\lambda + 2\mu)P_5(t) + KP_4(t)$$

$$\frac{d}{dt} P_4(t) = (3\lambda + 2\mu) \cdot C \cdot P_5(t) - (K + 3\lambda + \mu)P_4(t) + KP_3(t)$$

$$\frac{d}{dt} P_3(t) = (3\lambda + \mu) \cdot C \cdot P_4(t) - (K + 3\lambda)P_3(t) + KP_2(t)$$

$$\frac{d}{dt} P_2(t) = 3\lambda CP_3(t) - (K + 2\lambda)P_2(t)$$

$$\frac{d}{dt} P_1(t) = (3\lambda + 2\mu)(1 - C)P_5(t) + (3\lambda + \mu)(1 - C)P_4(t) + 3\lambda(1 - C)P_3(t) + 2\lambda P_2(t)$$

$$P_5(0) = 1, \quad P_4(0) = P_3(0) = P_2(0) = P_1(0) = 0$$

$P_i(t)$ represents the probability that there are i working modules at time t and all remaining modules failed.

The reliability of the system $R(t) = 1\ P_1(t)$.

Based on a great deal of numerical calculations using values of λ, μ, and C to reflect the state of the technology, we found that even when K is very small, such as K = 0.0001, the reliability of the system can still be

significantly improved compared to that of a system where transient failure modules cannot be reused.

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Applied Acoustics

EXPERIMENTAL STUDY ON EFFICIENCY OF PIEZOELECTRIC TRANSDUCER IN HIGH-POWER EXCITATION

Beijing YINGYONG SHENGXUE [APPLIED ACOUSTICS] in Chinese Vol 4 No 4, Oct 85 pp 14-16, 32

[Article by Lin Zhongmao [2651 0112 5399], Fang Fuquan [2075 4395 0356], and Su Dunzhen [5685 2415 3791], Institute of Acoustics, Chinese Academy of Sciences]

[Abstract] In an experimental study, the electrical measurement method is used to determine the efficiency of a sandwich-type piezoelectric transducer in high power operating conditions. Included in the study are the relationship of electroacoustic efficiency, load, and input electric power of the piezoelectric transducer, as well as the frequency characteristics of tranducer efficiency. In the mode of acoustic matching, the electroacoustic efficiency of the transducer is in excess of 90 percent, and the efficiency increases with the rising input electric power. In the operating load mode, efficiencies of two kinds of piezoelectric transducers are preliminarily measured in order to explore how to design transducers correctly. One table lists data showing the relationship between transducer efficiency and input power. Five figures show measurements of transducer efficiency; relationship between electroacoustic efficiency on the one hand, and load resistance and input electric power, on the other; frequency characteristic of electroacoustic efficiency; and efficiency of a semiperforated structure, wide frequency band transducer. The contents of the paper were reported at the 1981 All China Power Ultrasonics Conference. This paper was received for publication on 7 March 1984.

APPLICATION OF ADAPTIVE SEGMENTATION TO SIGNAL ANALYSIS IN UNDERWATER ACOUSTICS

Beijing YINGYONG SHENGXUE [APPLIED ACOUSTICS] in Chinese Vol 4 No 4, Oct 85 pp 23-32

[Article by Wu Guoqing [0702 0948 3237], Institute of Acoustics, Chinese Academy of Sciences]

[Abstract] The paper applies the Generalized Likelihood Ratio (GLR) segmentation technique for analyzing underwater echo signals; many desirable results are obtained. This indicates the applicability of the GLR segmentation technique in processing signals obscured by noise. The paper presents analytical results of two kinds of signals: echo waves from an island and from a submerged object. These signals are obscured by strong noises; some signals are undetectable by human ears. However, this segmentation technique is capable of detecting the signal boundary and determining the boundary position. The result shows the prospects of the linear prediction technique applied in processing underwater acoustic signals. Seven figures show the detection of single boundary, short segment test, power change test, segmentation in noise, detection of signal boundary of island echo waves, echo from immersing target, and weak echo from immersing target. The first half of the study was completed by the author when he did research work at the Southeastern Massachusetts University. Professor (Dr) C.H. Chen recommended the GLR segmentation technique. Colleagues at the laboratory No 1 of the Institute of Acoustics made recordings of the marine echo signals; Zhang Shuangrong [1728 7175 2837] inputted the simulated signals into a computer. The author expresses his gratitude to the above-mentioned persons. This paper was received for publication on 10 May 1984.

APPLICATION OF CLASS-D POWER AMPLIFIER IN UNDERWATER SOUND PROJECTOR

Beijing YINGYONG SHENGXUE [APPLIED ACOUSTICS] in Chinese Vol 4 No 4, Oct 85 pp 43-44, 42

[Article by Sun Enping [1327 1869 5493], Institute of Marine Instruments, State Oceanography Bureau]

[Abstract] In order to reduce energy consumption (power) and raise the operating efficiency of the underwater sound projector by emitting relatively high power with the use of small transistors, it is more desirable to use a transistorized class-D power amplifier. Sufficient proof has been gained in applications. This paper presents basic circuit characteristics and a test method using circuits as examples. The class-D power amplifier uses a transistor as an on-and-off switch. The transistor operates in the saturation and interruption zones of the volt-ampere characteristic curve. Since the saturated voltage drop of the transistor is quite low, this phenomenon reduces the transistor power consumption to a minimum and raises the energy conversion efficiency of the amplifier. Three figures show electrical principle of power surge stage and power amplification stage of an underwater acoustic signal transmitter, matching network of a transducer, and electrical principle of power testing. This paper was received for publication on 24 January 1984.

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A RAPID HIGH PRECISION SIMULATION METHOD OF CONTROL SYSTEM WITH SATURATED INPUT

Beijing YUHANG XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 4, 31 Oct 85 pp 1-7

[English abstract of article by Wang Zicai [3769 1311 2088] and Ge Wei [5514 5898]]

[Text] In this paper a method for simulation of a linear system with a saturated nonlinear element is presented. Its advantages are rapidity, high precision, large step length, etc. The high precision was achieved by means of Mastascusa's algorithm and the saturated nonlinear element was divided into different linear models.

This method has been applied to the simulation of a missile's longitudinal control system and the results are shown to be satisfactory.

STUDY OF PREDICTION OF LIQUID FUEL CAPTURE BY FLAMEHOLDER DOWNSTREAM OF PLAIN ORIFICE INJECTOR UNDER UNIFORM CROSS AIR FLOW

Beijing YUHANG XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 4, 31 Oct 85 pp 8-15

[English abstract of article by Zhu Junyong [2612 0193 0516], Jin Rushan [6855 1172 1472] and Cao Minghua [2580 2494 7520]]

[Text] Based on the "flat-fan spray model" and "fuel capture model" proposed previously, liquid fuel spray captured by the V-gutter flameholder can be predicted. The study reported in the present paper includes:
(1) The effect of different factors, such as air flow parameters, injector pressure drop and the distance between the V-gutter and injector on fuel spray capture by a horizontally positioned flameholder in a wide range of parameters;
(2) A comparison between the fuel spray capture by horizontally and vertically positioned flameholders;
(3) The fuel spray capture by a V-gutter flameholder positioned between horizontal and vertical installation;
(4) Fuel spray capture by a V-gutter from an injector which has been positioned with partially contra-stream injection;
(5) The correlation for maximum fuel spray capture is obtained.

Analysis indicates that the installation angle β of the V-gutter and partial contra-stream injection angle α are two important design variables in controlling the fuel spray capture.

A STUDY OF THE FRACTURE OF CARBON-CARBON COMPOSITES

Beijing YUHANG XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 4, 31 Oct 85 pp 40-48

[English abstract of article by Zhao Jiaxiang [6392 4471 4382]]

[Text] In this paper the effect of testing parameters on the values of the work-of-fracture of carbon-carbon composites is studied, and the testing parameters for measuring the work-of-fracture of carbon-carbon composites are determined. The work-of-fracture of three different kinds of carbon-carbon composites (3D orthogonal fine woven carbon-carbon composite, carbon felt reinforced by carbon fibers carbon-carbon composite and semi-random chopped fibers carbon-carbon composite) is measured and compared with those of graphites, glassy carbons, glass and fused SiO_2. The characteristic features of fracture for the different carbon-carbon composites are studied and the fracture modes and propagation of cracks as well as the weak links are pointed out.

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Nuclear Electronics

TEST OF HIGH TEMPERATURE BEHAVIOR OF IN-CORE MINIATURE DIRECT CURRENT FISSION CHAMBER IN REACTOR

Beijing HEDIANZIXUE YU TANCE JISHU [NUCLEAR ELECTRONICS AND DETECTION TECHNOLOGY] in Chinese Vol 5 No 5, Sep 85 pp 271,273, 279

[Article by Zhao Xiuqing [6392 4423 3237], Beijing Nuclear Instrument Plant]

[Abstract] The paper describes the test status of the high temperature behavior of a miniature direct current fission chamber in the in-core channel of a swimming pool type, light water reactor (LWR) with a simple gamma heater, and presents the saturation properties in the high temperature and temperature cycle. The test indicates that the saturation behavior, and cold and hot temperature cycles behavior are satisfactory under high flux irradiation. High temperature in-core irradiation tests can be conducted on small detector and miniature elements. The test method is simple; the required temperature can be obtained by adjusting the reactor temperature and position of the gamma heater. The relatively lengthy time of high temperature irradiation test can be performed when the reactor operates at constant load. However, the behavior test at different detector temperatures cannot be conducted for a constant power reactor. Three tables list the main structure parameters and performance values of a fission chamber, temperature data on the gamma heater at different power ratings, and temperature cycle data of the miniature fission chamber. Six figures show a high-temperature test setup, the structure of gamma heater, measurement of average current in the fission chamber, temperature cycle testing setup, and saturation curves of fission chamber at a high temperature and temperature cycle. The author is grateful to Huang Yucai [7806 3768 2088], Gao Chun [7559 2504], Wang Wenzi [3769 2429 3320], Sun Jinghai [1327 2529 3189] and Zhou Dejun [0719 1795 0689] for their assistance.

A FAST LEADING-EDGE PULSE GENERATOR

Beijing HEDIANZIXUE YU TANCE JISHU [NUCLEAR ELECTRONICS AND DETECTION TECHNOLOGY] in Chinese Vol 5 No 5, Sep 85 pp 294-297

[Article by Wang Rendao [1769 0088 6670], Institute of Modern Physics, Chinese Academy of Sciences]

[Abstract] The pulse generator consists of ECL semiconductor integrated circuits, high speed transistors and step restorer diodes, among others; its circuitry is simple. The leading edge of the output pulse is less than 100 ps, and the output impedance is 50 Ω. An ECL "four-wire receiver" connected as a closed loop circuit is used in the oscillator section of the set. The pulse frequency varies as low as (less than) 10 Hz and as high as 100 MHz. The control of pulse width is based on the subtraction of two pulse widths. The output pulse width may be less than 10 ns and the maximum width may be as wide as an oscillator half-cycle. The pulse amplitude is continuously adjustable from $\pm$35 mV to $\pm$5 V. Seven figures show the operating principle of the oscillator stage, a simplified logic diagram, waveforms at various points, a rectifier circuit in the first stage, positive pulse channel circuit, and an adjustable power source. The paper was received for publication on 27 April 1984.

TYPE GDB-110 LARGE AREA, FAST RESPONSE PHOTOMULTIPLIER

Beijing HEDIANZIXUE YU TANCE JISHU [NUCLEAR ELECTRONICS AND DETECTION TECHNOLOGY] in Chinese Vol 5 No 5, Sep 85 pp 303-306

[Article by Song Yonglu [1345 3057 4389], Xu Deqi [1776 1795 4388], Yu Biao [0060 1753], and Li Shou [2621 0649], Beijing Nuclear Instrument Plant]

[Abstract] The model GDB-110 photomultiplier is a tube with an hyperbolic terminal window and a semi-transparent bialkali photocathode. The effective cathode diameter is 110 mm; borosilicate glass is used for the window. The optical spectral region is 320 to 650 nm. The photomultiplier has high detection efficiency, high response speed, and large increments. The voltage divider of model GDB-110 is designed to meet performance and use requirements; it includes model A and B voltage dividers as shown in one of six figures in the paper. During detection, whether scintillation or Cerenkov radiation, the radiation intensity is very low. Therefore, only by increasing the photocathode area can the collection efficiency be improved. The model GDB-110 is adaptable to the above-mentioned situation. Five remaining figures show the outside dimensions of the photomultiplier; the relationships between anode luminosity sensitivity and operating voltage, and between time and voltage; single electron spectrum and noise spectrum; and the relationship between the secondary emission coefficient and interpole voltage. Two tables list main technical indexes and time characteristics. The authors are grateful to Li Jin [2621 6855] of the Institute of Atomic Energy of the Chinese Academy of Sciences, and Yang Baozhong [2799 0202 0022] of the China University of Science and Technology.

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